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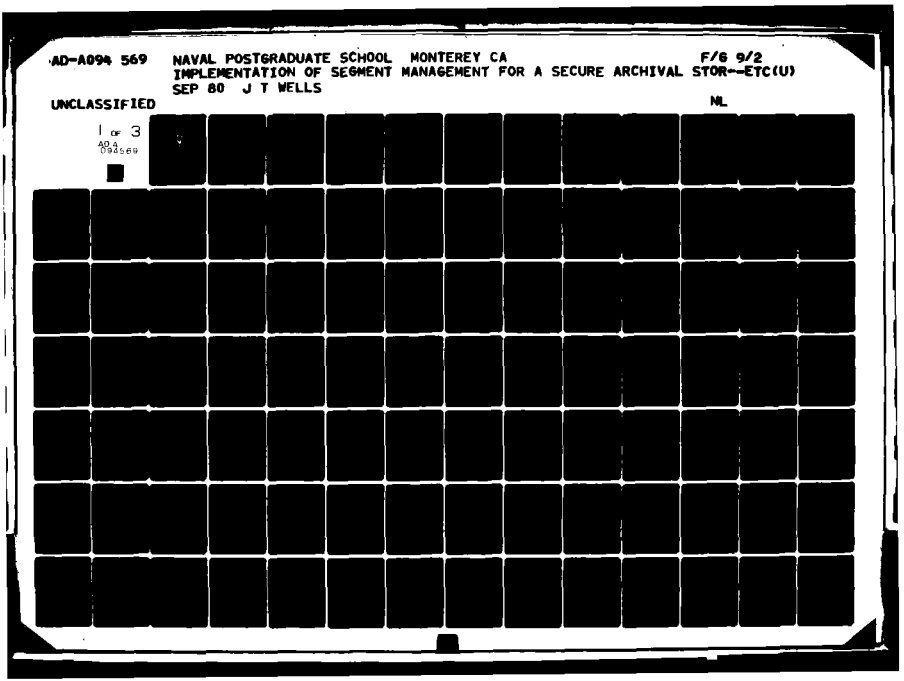

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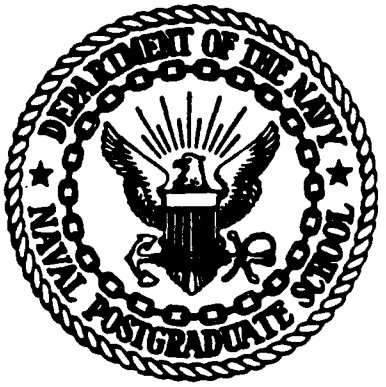

THESIS

IMPLEMENTATION OF SEGMENT MANAGEMENT
FOR A SECURE ARCHIVAL STORAGE SYSTEM

by

John Timothy Wells

September 1980

Thesis Advisor: R. R. Schell

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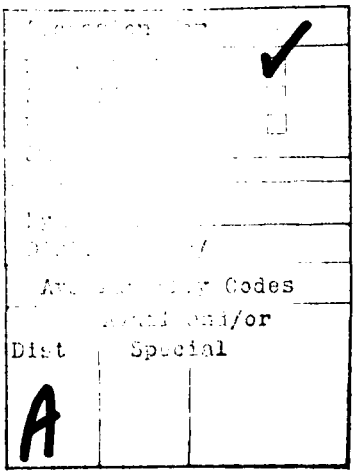

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Implementation of Segment Management
for a
Secure Archival Storage System

by

John T. Wells
Lieutenant Commander, United States Navy
B.S., University of Mississippi, 1970

Submitted in partial fulfillment of the
requirements for the degree of

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from the

NAVAL POSTGRADUATE SCHOOL
September 1980

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ABSTRACT

This thesis presents an implementation of segment management for the security kernel of a secure archival storage system. The basis for this implementation is a family of secure, distributed, multi-microprocessor operating systems designed to provide multilevel internal computer security and controlled sharing of data among authorized users. This implementation provides address space management for individual processes, based on segmentation as a memory management scheme. Non-discretionary information security is provided through enforcement of a security policy based on a lattice structure that allows flexibility in representing different security policies; the Department of Defense (DoD) security classification system is the security policy represented in this thesis. Implementation was completed on the ZILOG Z8000 microprocessor.

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I wish to express my deepest appreciation to my advisor Lt. Col Roger Schell. His patience and assistance were invaluable. Thanks also to my reader Professor Lyle Cox and to Lcdr. Ed Moore, Lcdr. Steve Reitz, and Lt. Al Gary. Finally, special thanks to my closest friend (and wife) Susan, who always supports me, whatever the endeavor.

I. INTRODUCTION

This thesis addresses the implementation of the segment management functions of an operating system known as the Secure Archival Storage System or SASS. This system, with full implementation, will provide: (1) multilevel secure access to information (files) stored in a "data warehouse" for a network of multiple host computers, and (2) controlled data sharing among authorized users. The correct performance of both of these features is directly dependent upon the proper implementation of the segment management functions addressed in this thesis. The issue of access to sensitive information is addressed by the Non-Discretionary Security Module, which mediates all non-discretionary access to information. Sharing of information is accomplished chiefly through the properties of segmentation, the SASS memory management scheme that is supported by the Memory Manager Module and the Segment Manager Module. The implementation of segment management for SASS is thus integral to the attainment of the two key goals that SASS was designed to achieve. This implementation addresses the Non-Discretionary Security, Distributed Memory Manager (the interface to the Memory Manager Process), and Segment Manager modules.

A. BACKGROUND

O'Connell and Richardson provided the design for a family of secure, distributed, multi-microprocessor operating systems from which the subset, SASS, was later derived [6]. In their work, two of the primary motivations were to provide a system that (1) effectively coordinated the processing power of microprocessors and (2) provided information security.

The basis for emphasis on utilization of microprocessors is not purely that of replacing software with more powerful (and faster) hardware (microprocessors) but is also an economic issue. Software development and computing operations are becoming more and more expensive, putting further pressure on system designers to increasingly utilize people solely for system functions that computers cannot perform in a cost effective manner. Microcomputers, on the other hand, are becoming less and less expensive and are, therefore, increasingly being used for more functions.

The need for information security has been gradually recognized as the uses of computers have expanded. As security needs for specific computer systems have been recognized, attempts have been made to modify the existing systems to provide the desired security. The results have been systems that could not be certified as secure and/or which have failed to resist penetration efforts, i.e. systems which, in effect, did not provide adequate

information security. It has become clear that, in order to be certifiably secure, a computer system must have security designed in from first principles [10,11]. Such is the case with SASS. Information security was and continues to be a chief design feature. Integral to the design goal of information security were two related goals. One of these goals was to provide multilevel controlled access to a consolidated "warehouse" of data for a network of multiple host computers. The other key goal was to provide for controlled sharing among the computer hosts.

A brief background of prior work relative to SASS follows. O'Connell and Richardson originated the design of a secure family of operating systems. Their design provided two basic parts for their system -- the supervisor (to provide operating system services) and the kernel (to provide for physical resource management). The design of the SASS supervisor was completed by Parks [7]. No implementation or further design effort on the supervior has followed, to date. The initial design of the kernel was completed by Coleman [1]. That design described the kernel in terms of seven modules:

1. Gate Keeper Module -- provided for ring-crossing mechanism and thus isolation of the kernel.
2. Segment Manager Module -- provided for management of segmented virtual memory.
3. Traffic Controller Module -- multiplexed processes onto virtual processors and supports the inter-

process communication primitives Block and Wakeup. Block and Wakeup.

4. Non-Discretionary Security Module -- mediated non-discretionary security access attempts.

5. Inner Traffic Controller Module -- multiplexed virtual processors onto real processors and provided the Kernel synchronization primitives Signal and Wait.

6. Memory Manager Module -- managed main memory and secondary storage.

7. Input-Output Manager -- managed the moving of information to external devices outside the boundaries of the SASS.

Refinement of the kernel design and partial implementation was completed by Gary and Moore [4] in conjunction with Reitz [9]. The resultant description of the kernel as a result of their work was:

1. Gate Keeper Module

2. Segment Manager Module

3. Event Manager Module -- worked with the Traffic Controller to manage the "event data" associated with the IPC mechanism of eventcounts and sequencers.

4. Non-Discretionary Security Module

5. Traffic Controller Module -- replaced Block and Wakeup with Advance and Await (to implement Supervisor IPC mechanism of eventcounts and sequencers).

6. Memory Manager Module

7. Inner Traffic Controller Module

Reitz implemented the Traffic Controller Module and Inner Traffic Controller Module. Gary and Moore completed a

detailed design of the Memory Manager, originated the Memory Manager code (written predominantly in PLZ/SYS), selected a thread of the code, hand compiled it into PLZ/ASM and ran it on the Z8000 developmental module.

The design and implementation works mentioned above provided the design base for this implementation. Refinements were made as needed and are discussed in Appendix G of this thesis. A broader description of the current state of SASS will be provided in the next section.

B. SECURE ARCHIVAL STORAGE SYSTEM OVERVIEW

This section presents a brief summary of the current design state of the Secure Archival Storage System. The purpose of this summary is to provide continuity (interface) between this and previous work relative to SASS, and to enhance understanding of the evolution of the more detailed and system specific information provided later in this thesis.

1. Levels of Abstraction

The original design for a family of secure, distributed operating systems (which was the basis for the development of SASS) used effectively the concept of levels of abstraction as a design methodology tool. Just as this tool allows for clarity and simplification in conceptualizing and designing a system, it also enhances the ability to clearly and succinctly describe that system's

design. Thus, an abstract system overview (description) of SASS will be presented here. Figure 1 represents that overview (illustrated for a single host system for clarity). There are four levels of abstraction:

Level 3 -- the Host computer systems

Level 2 -- the Supervisor

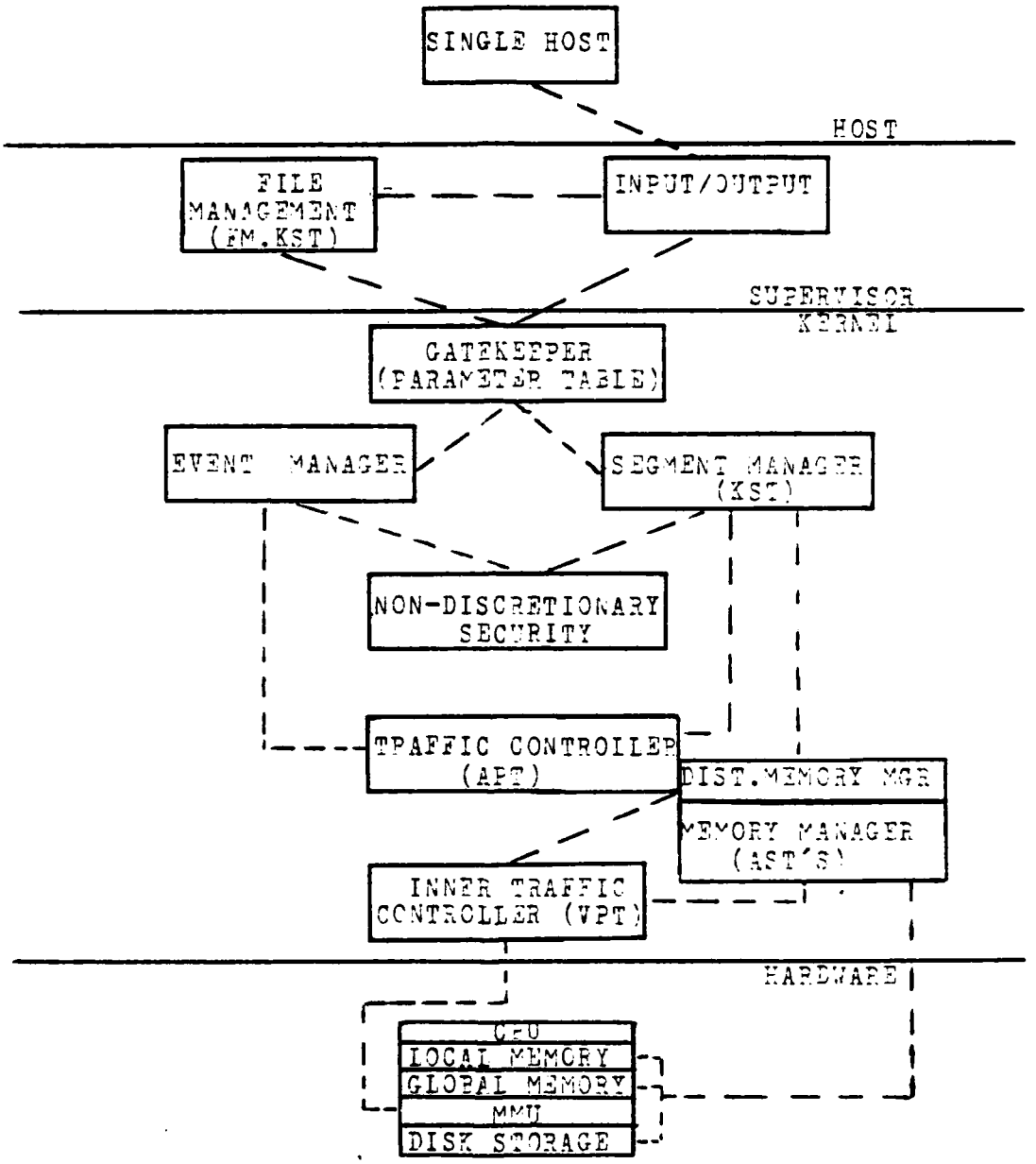
Level 1 -- the Kernel

Level Ø -- the Hardware

The Gate Keeper Module is logically the boundary between the Supervisor and the Kernel and thus will not be discussed within either of these levels, but rather separately.

2. Level Three - Host Computer(s)

Level three consists of the Host computer systems. There may be a variable number of host computers of any type (e.g., micro, mini, etc). Each host may be used to create and manipulate files of a fixed, predetermined degree of sensitivity (or security classification). Once a user of a host computer system completes work on a particular file, they can permanently store that file on the SASS (and, of course, may later again access the same file by requesting the SASS to provide it to them). Each host computer system is individually wired to an I/O port of the Z8ØØ1. Each of the ports has fixed access level.



Note: Databases are shown in parenthesis

Figure 1. SASS System Overview (Single Host)

If a multilevel secure Host desires to handle data at two levels (e.g., secret and unclassified), it will use two connections to the SASS. Physical and/or cryptographic protection of the hardwire connections is assumed.

3. Level Two - Supervisor

Level two is the Supervisor. A proper description of the Supervisor is "that component of the SASS that executes in the outer, less privileged domain (normal mode) of the Z8001 microprocessor, and is responsible for the SASS - Host computer interface". Integral to this description (and the Kernel's description) is the concept of a "domain", that can be described using four other terms that also need to be defined: "process", "address space", "segment", and "segmentation". Madnick and Donovan [5] define a process as the locus of points of a processor executing a collection of programs; the collection of programs and data that are accessed in a process forms that process's address space. A segment is defined as a logical grouping of information, such as a subroutine, array, or data area, and segmentation is defined as the technique for managing segments of an address space. It is convenient then, since the SASS uses segmentation as a memory management scheme, to more specifically define a SASS process address space as the collection of segments that are accessed (or are accessible) in that process. A domain is conceptualized in SASS due to the necessity to isolate the Kernel from all possible

outside influences. To achieve this, a process' address space is divided into a hierarchial arrangement of segment accessibility, viz., a set of hierarchial protection domains called protection rings. In SASS, there are two domains implemented (and necessary as a minimum): the Supervisor domain and the Kernel domain. The Z8001 microprocessor provides the SASS with two execution modes that, along with Kernel software, implement these domains: a system (Kernel) mode that provides access to all segments (and machine instructions), and a normal (Supervisor) mode that provides access to a subset of the segments (and machine instructions). Thus, the Supervisor operates in the outer or less privileged domain.

The Supervisor contains those segments of the system that are necessary to perform the SASS - Host computer system interface (construct and manage a file hierarchy and control I/O between the SASS - Host). It is built upon the Kernel and performs the Host's requests by calls to the Kernel (the calls are validated by the Gate Keeper prior to invocation of Kernel functions). Two surrogate processes, input/output (I/O) and file management (FM), are assigned to each Host computer system at system generation. The FM process directs all interaction between the SASS and a Host computer system. Specific functions include the management of the Host's file hierarchy (using the FM Known Segment Table (FM_KST) as a database) and discretionary security

access management (checking and maintaining an Access Control List (ACL) for each file within the file hierarchy). Controlling discretionary security with an ACL allows authorized users to specify who may use segments (files) within the confines of the non-discretionary security policy. Discretionary security will be defined and discussed in more detail in chapter II.

The I/O process acts in a slave mode to the FM process and is responsible for all input/output between the Supervisor and the host computer systems. Data is transferred between the Host and the SASS via fixed size "packets" (a grouping of data in a specified format). To transmit and receive packets between the Host and the SASS a "protocol" (or formal passing method) must exist between them. The I/O process is responsible for the SASS-Host protocol (Parks [7] designed a multi-packet protocol). Parks provides a detailed description of the Supervisor as it was originally designed.

4. Gate Keeper Module

The Gate Keeper is a software ring-crossing mechanism that provides for the isolation of the Kernel (viz., making the Kernel procedures tamperproof). The notion of a "ring-crossing" mechanism is an extension of the previous discussion of domains since "protection rings" is simply another term for hierarchial domains (such as the SASS arrangement of the Kernel and the Supervisor). All

calls to the distributed kernel and IPC with the Memory Manager must pass through the Gate Keeper (viz., it is the sole entry point into the Kernel from the Supervisor). The Gate Keeper is a trap handler; when invoked by the supervisor domain of a process, it must save the supervisor domain registers and stack pointer. The argument list provided by the supervisor domain's call (included in this list must be the identity of the kernel domain function (procedure) being called) is validated and, if correct, results in invocation of the appropriate procedure. Hardware preempt interrupts are masked upon entry into the Kernel. When returning (exiting the Kernel) the following actions occur: (1) software virtual preempt interrupts are unmasked (if a virtual preempt interrupt has occurred, the Traffic Controller's virtual interrupt handler is called vice the Kernel being exited), (2) hardware interrupts are unmasked, (3) the return arguments are passed to the Supervisor, and (4) the Supervisor domain stack pointer and registers are restored, returning the execution point to the Supervisor domain. An error code is returned and the Kernel is not invoked when an invalid call is encountered by the Gate Keeper. The database of the Gate Keeper is the Parameter Table. This table contains an entry for each permitted kernel function (e.g., Create_Segment, Delete_Segment, etc.) and is used to validate the correctness of the range (size) of the parameters passed.

5. Level One - Kernel

Level one is the Security Kernel (or Kernel). The Security Kernel in the inner or most privileged domain (system mode of the Z8001) and is responsible for managing the real resources of the hardware system (viz., memory, microprocessor, external devices, and input/output ports), and for enforcing the non-discretionary security policy for the SASS. The Kernel is divided into two major components. The first is the distributed kernel, i.e., the modules in the Kernel whose segments are placed in (or distributed in) the address spaces of each Supervisor process; the distributed kernel consists of the Gate Keeper (already discussed), the Segment Manager, the Event Manager, the Traffic Controller, and the Inner Traffic Controller. The second component is the non-distributed kernel and consists of the asynchronous memory manager process (which is contained entirely within the Kernel address space). There is a memory manager process for each hardware processor in the SASS. The following section will identify and briefly describe each of the Kernel's distributed and non-distributed system components.

a. Segment Manager

The Segment Manager (the focal point of this thesis) is a component of the distributed kernel; its function is the creation and management of a segmented virtual memory for the process. Actual memory management

functions are completed via calls for IPC to the Memory Manager process. Calls to (viz., entries into) the Segment Manager are received via the Gate Keeper from the Supervisor. These entries (viz., extended instructions) are:

1. Create_Segment -- add a new segment to the SASS.
2. Delete_Segment -- remove a segment from the SASS.
3. Make_Known -- add a segment to a process' address space.
4. Terminate -- remove a segment from a process' address space.
5. SM_Swap_In -- move a segment from secondary storage to main memory.
6. SM_Swap_Out -- move a segment from main memory to secondary storage.

The process local database used by the Segment Manager is the Known Segment Table (KST). The KST contains entries for all segments in the address space of that process. The Segment Manager will be described in more detail in chapters II and III.

b. Non-Discretionary Security Module

The Non-Discretionary Security (NDS) Module is a component of the distributed kernel; its function is the enforcement of the non-discretionary security policy in effect in the SASS. Although the implementation presented in this thesis reflects the DoD non-discretionary security policy, any security policy that can be represented by a

lattice structure may be similarly implemented. To implement a different policy (e.g., Privacy Act or a local policy) requires only replacement of the Non-Discretionary Security Module (viz., the modules calling it can be left intact with no changes required to them). The NDS Module creates the extended instruction set CLASS_EQ and CLASS_GE. The Non-Discretionary Security Module and the information security concepts which form its basis will be discussed in more detail in chapters II and III.

c. Event Manager

The Event Manager is a component of the distributed kernel; it is invoked by the Supervisor processes via the Gate Keeper. This module's function is to manage event data. Event data is associated with a global object (called an eventcount). An eventcount is a count of the number of events (e.g., the number of read or write accesses of a segment) that have occurred so far in the execution of a system. In SASS, as a naming convention, each Supervisor segment has two eventcounts associated with it. These eventcounts (Instance1 and Instance2) are stored in a Memory Manager database. The Event Manager creates the extended instruction set READ and TICKET; they are based on the mechanism of eventcounts and sequencers (used for the synchronization of concurrent processes). READ is a call that returns the current value of the eventcount. TICKET, using a nondecreasing integer called a sequencer (also

associated with each Supervisor segment), provides a complete time ordering of possibly concurrent events. Each invocation of the function TICKET increments the value of the sequencer and returns it to the caller. The eventcounts/sequencer synchronization mechanism is described in detail by Reed and Kanodia [8] while an excellent abridged discussion is presented by Gary and Moore [4].

d. Traffic Controller

The Traffic Controller (TC) is a component of the distributed kernel; it is responsible for multiplexing processes onto virtual processors. A virtual processor is a data structure that contains a complete description of a process in execution on a physical processor at a given instant. A "complete description" is defined to consist of the execution point or current CPU state and the address space (set of segments accessible by that process) of the process in execution. The Traffic Controller also creates the extended instructions ADVANCE and AWAIT which are used to implement eventcounts and sequencers, the inter-process communication (IPC) mechanism invoked by the Supervisor, and the extended instruction PROCESS_CLASS. PROCESS_CLASS is invoked by the Segment Manager and returns the label (classification) of the current process. The Traffic Controller is half of a two level traffic controller; the other half is the Inner Traffic Controller, which multiplexes the virtual processors onto physical processors.

The database for the Traffic Controller is the Active Process Table (APT), a fixed size, system wide database, that contains a permanent entry for each Supervisor process created at system generation (in the SASS the processes are then active for the life of the system). The APT structure is shown in figure 2. The scheduling algorithms and a detailed discussion of the current state of the Traffic Controller are provided by Reitz [9].

e. Inner Traffic Controller

The Inner Traffic Controller (ITC) is a component of the distributed kernel; it is the other half of the two level traffic controller and its function is to multiplex (temporarily bind) virtual processors (VP) to the real processors of the system; a design choice was made to provide each system CPU with a small fixed set of virtual processors. Two of the VP's are the Memory Manager VP and the Idle VP (the latter is permanently bound to the lowest priority virtual processor and is scheduled by the ITC only when there is no useful work for the CPU). The remaining VP's have Supervisor processes temporarily bound on them by the Traffic Controller. Another function of the ITC is to furnish inter-process services for VP's in the kernel ring. This is done by providing the primitives SIGNAL and WAIT, that are used by processes in the Kernel ring to communicate with other Kernel ring processes.

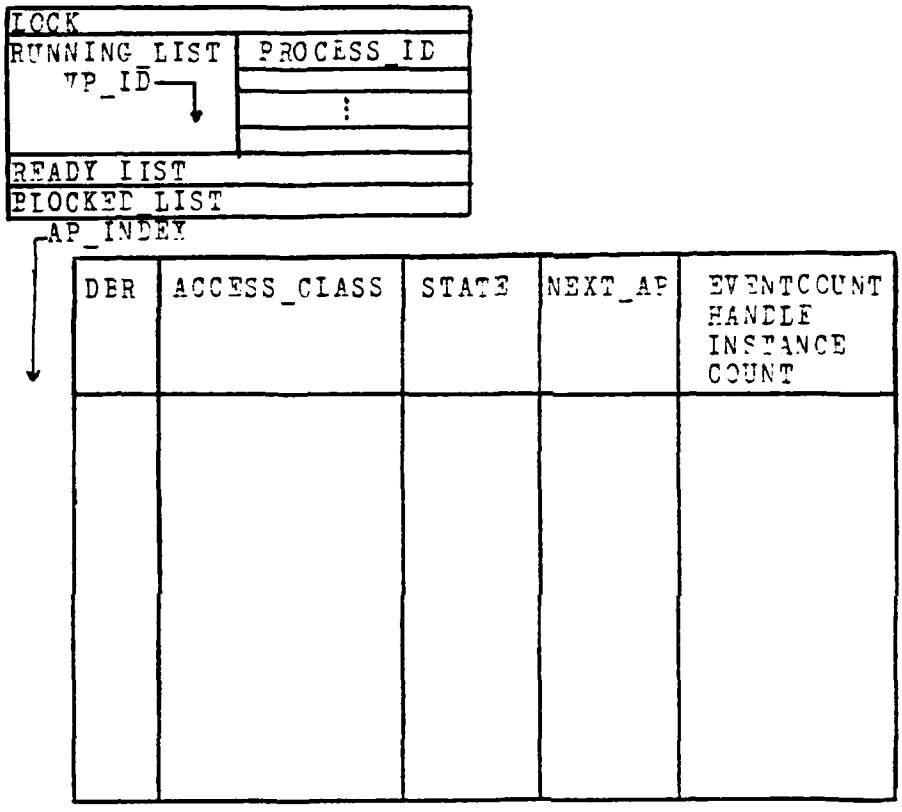


Figure 2. Active Process Table

```
APT             RECORD [LOCK            WORD
                        RUNNING_LIST    RUNNING_ARRAY
                        READY_LIST      WORD
                        BLOCKED_LIST    WORD
                        AP              ARRAY
                                [NR_PROCESSES  AP_TABLE]
                        ]

AP_TABLE        RECORD [NEXT_AP         AP_POINTER
                        DER             ADDRESS
                        ACCESS_CLASS    LONG
                        STATE           INTEGER
                        NEXT_AP         WORD
                        EVENT_COUNT     EVENT_TABLE
                        ]

EVENT_TABLE     RECORD [HANDLE          WORD
                        INSTANCE        WORD
                        COUNT           WORD
                        ]

AP_POINTER      WORD

ADDRESS         WORD
```

Figure 2. Active Process Table (continued)

This is the mechanism used within the Kernel to provide multiprogramming (process switching). The ITC Module creates the extended instruction set: SIGNAL, WAIT, SWAP_VDBR, IDLE, SET_PREEMPT, TEST_PREEMPT, and RUNNING_VP. The functions of SIGNAL and WAIT have been discussed already. SWAP_VDBR provides the TC with a means to schedule processes on the currently running VP. IDLE loads an "idle" process on the currently running VP. SET_PREEMPT sets the virtual preempt interrupt flag on a specified VP (specified by the TC). TEST_PREEMPT provides the virtual preempt unmasking mechanism that is executed each time a process tries to move from the Kernel to the Supervisor domain. The database used by the Inner Traffic Controller is the Virtual Processor Table (VPT). There is one system wide table with entries for each physical processor in the system. The VPT for a single processor system (such as SASS) is shown in figure 4. The scheduling algorithms and a detailed discussion of the current state of the Inner Traffic Controller are provided by Reitz[9].

f. Memory Manager

The Memory Manager Module is the only component in the non-distributed kernel. There is a Memory Manager process dedicated to each physical processor (CPU) in the system.

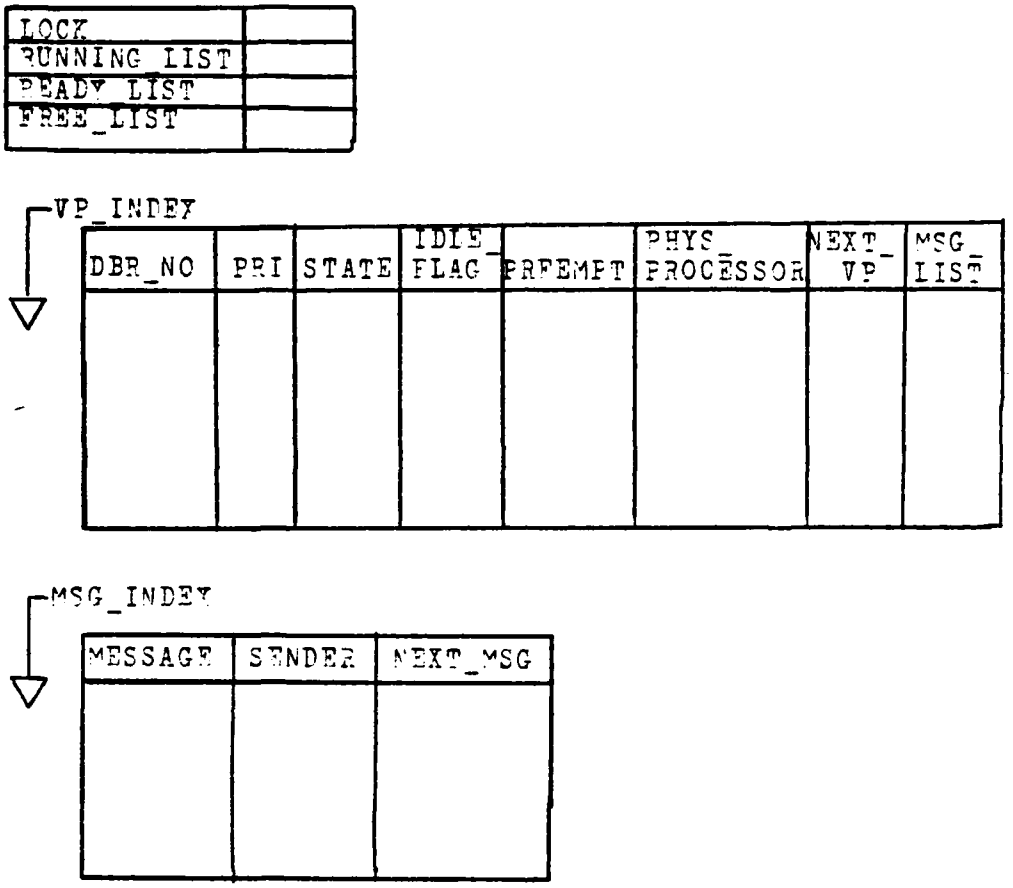


Figure 3. Virtual Processor Table

```
VPT             RECORD [LOCK            WORD
                        RUNNING_LIST    VP_INDEX
                        READY_LIST      VP_INDEX
                        FREE_LIST       MSG_INDEX
                        VP              ARRAY
                                        [NR_VP  VP_TABLE]
                        MSG_Q           ARRAY
                                        [NR_VP  MSG_TABLE]

VP_TABLE        RECORD [DBR             ADDRESS
                        PPI             WORD
                        STATE           WORD
                        IDLE_FLAG       WORD
                        PREEMPT         WORD
                        PHYS_PROCESSOR  WORD
                        NEXT_READY      VP_INDEX
                        MSG_LIST        MSG_INDEX
                        ]

MESSAGE         ARRAY  [16              BYTE]

ADDRESS         WORD

VP_INDEX        INTEGER

MSG_INDEX       INTEGER
```

Figure 3. Virtual Processor Table (continued)

The Memory Manager is responsible for managing the real memory resources of the system, viz., local and global main memory and secondary storage. The memory manager manages the local and global memory in such a way as to control bus contention in the multi-microprocessor environment. Thus, each CPU has its own local memory to store process local segments and there is a global memory to which every CPU has access and in which shared, writeable segments must be stored. This requirement is to ensure that a current copy is always accessed for a shared, writeable segment. To keep bus contention between processors that access global memory to a minimum, whenever possible (viz., in all cases but shared, writeable segments) segments are to be stored in local memory. The Memory Manager has several databases, primary of which are the system wide Global Active Segment Table (G_AST) and the per processor Local Active Segment Table (L_AST). A more detailed description of the Memory Manager Module is presented in chapters II and III.

6. Level Zero - Hardware

The Z8001 microprocessor, Z8010 Memory Management Unit (MMU), local and global memories, and secondary storage form the SASS' basic hardware group. Since the design calls for SASS to exist in a multi-microprocessor environment, there will be multiple copies of some elements of the group, e.g.,CPU, local memory. The Z8001 microprocessor is a

register oriented machine that has sixteen 16-bit general purpose registers. When operated with the MMU, the desired capabilities of memory segmentation, multiple domains, and process switching are realized. The MMU consists of a set of registers (64) to implement the descriptor list (or descriptor segment); viz., each register contains the descriptor (containing the attributes) of a particular segment. Zilog [14] provides a detailed description of the Z8001 microprocessor and Zilog [15] describes the Z8010 MMU.

C. STRUCTURE OF THE THESIS

This thesis describes the implementation of the segment management functions for the SASS. The design "base" evolved from the original secure family of operating systems identified and designed by O'Connell and Richardson. A block structured language, PLZ/SYS, was used in this and previous design efforts, while implementation was completed using PLZ/ASM assembly code. PLZ/SYS is described by Snook [12] and Conway [2] while PLZ/ASM is described by Zilog [13]. A compiler for PLZ/SYS to PLZ/ASM code translation was not available. As a result, implementation included the added step of manual translation of PLZ/SYS code to PLZ/ASM code to facilitate testing and debugging.

In this chapter an introduction to SASS was provided through discussion of its background and an overview of the entire system. A summary of the extended instruction sets

created by the Kernel components and a summary of the Kernel databases is presented in figures 4 and 5.

Chapter II of this thesis will present a description of the segment management functions in SASS. Discussion of the theory behind information security and its implications to SASS is also provided. The modules encompassed by segment management will be discussed in terms of their design, functional purpose, and database descriptions.

Chapter III presents the implementation of segment management (viz., the segment manager, non-discretionary security, and distributed memory manager modules). Description of design and implementation criteria, and choices made during implementation are discussed in this chapter.

Chapter IV provides the conclusions reached, status of research, and recommendations relative to continuation and extension of the work.

Appendices include PLZ/ASM code for the modules, the program listings for the Segment Manager demonstration and a summary of the refinements made to previous design/code relative to SASS.

MODULE	INSTRUCTION SET	
Segment Manager	Create_Segment	Delete_Segment
	Make_Known	Terminate
	SM_Swap_In	SM_Swap_Out
Event Manager	Read	Ticket
Non-Discretionary Security Traffic Controller	Class_EQ	Class_GE
	Advance	Await
	Process_Class	
Inner Traffic Controller	Signal	Wait
	Swap_VDBR	Idle
	Set_Preempt	Test_Preempt
	Running_VP	
Memory Manager	MM_Create_Entry	MM_Delete_Entry
	MM_Activate	MM_Deactivate
	MM_Swap_In	MM_Swap_Out

Figure 4. Extended Instruction Sets

MODULE	DATABASE
Gate Keeper	Parameter Table
Segment Manager	Known_Segment_Table (KST)
Traffic Controller	Active_Process_Table (APT)
Inner Traffic Controller	Virtual_Processor_Table (VPT)
Memory Manager	Global_Active_Segment_Table (G_AST)
	Local_Active_Segment_Table (L_AST)
	Memory_Management_Unit_Image (MMU_Image)
	Alias_Table
	Disk_Bit_Map
	Global_Memory_Bit_Map
	Local_Memory_Bit_Map

Figure 5. Kernel Databases

II. SEGMENT MANAGEMENT FUNCTIONS

A conceptual discussion of the functions associated with segment management is presented in this chapter. As previously mentioned, two dominating goals of SASS were to provide multilevel controlled access to information and to provide for controlled sharing of information. The major factor in controlled access (which, in effect, refers to information security) and in information sharing is the concept of segmentation. Segmentation, data sharing, and information security will be discussed relative to their value to SASS.

A. *BASIC CONCEPTS/DISCUSSION*

1. Segmentation

Segmentation has previously been defined as the technique for managing segments of an address space where a segment is defined to be a logical grouping of information which possesses the qualities of having uniform attributes, being logical (vice physical), being visible to the user and being arbitrary in size. Based upon this notion, a process' address space is then viewed as consisting of the collection of segments that the process may access. In a segmented environment all addresses require two components: (1) a segment specifier (number) and (2) the location (offset) within the segment. Each segment may have attached to it

logical attributes that enable certain important control features to be implemented. Controlled access and information sharing implementation is specifically facilitated. By including classification and access information in a segment's logical attributes, a method to enforce information security is provided. Segmentation supports information sharing since it allows a segment to belong to more than one address space, that is, a single physical copy may be accessed by more than one process. Controlled physical sharing of information (within access constraints) is achieved, in the case of SASS, by putting segments which are shared and writeable into the system's global memory (vice a copy in each local memory).

Segmentation also facilitates the implementation of multiple protection domains in SASS. A process' address space is divided into domains or arrangements of segment accessibility. The Kernel domain is the most privileged and includes all segments of the address space, while the supervisor domain is less privileged and excludes segments representing the management of the shared resources by more than one process.

2. Data Sharing

The facility to share a single segment (and thus a single copy of the information to be accessed) by many processes is a significant feature that is facilitated via segmentation. In short, by processes sharing a common

physical copy of a segment, there is no requirement for duplicate copies and thus no possibility exists of having copies that are not up to date. In SASS, given the global memory/local memories environment, the policy is to put copies of segments in local memory except in the case of shared and writeable segments, which are placed in global memory for sharing purposes among processes with the appropriate access.

Segmentation is vital to this policy since only through explicit segmentation can SASS know the read/write properties of the information. Thus, segments which are shared but have read only access (by all processes that may access it) are not put into global memory but rather into the local memory of each of the processes that may access it (viz., multiple copies exist). There is no possibility of the multiple copy/ out of date copy problem since only read access is allowed. However, this is a seeming waste of memory and nonuse of the sharing facility provided by segmentation. The justification is based on a design decision motivated by another goal of SASS -- reduction of bus contention among processors accessing global memory. This is considered to be of more importance than the saving of memory space offered by single copy sharing of information; as stated before, the cost of memory has gone down significantly in the last few years thus reducing its influence on decisions such as this.

3. Information Security

Information security in a computer environment only recently began to receive the attention that it deserves. Few people have been far sighted enough to view computer security in an analogous manner to communications security (an area which has received considerable military and commercial attention throughout history, especially since the advent of electronic communications). Only through harsh and embarrassing lessons has the importance of computer security being recognized. The range of problems encountered covers virtual every level of computer usage: banks and commercial enterprises are victims of theft through the felonious use of computers; universities are the victims of undesired users entering their systems and either maliciously or accidentally destroying valuable programs; and the military faces the real possibility that classified material is being accessed by foreign agents without our knowledge and/or crucial systems are being tampered with without our knowledge. The effects of these type actions may be as small as simple embarassment or as serious as undermined military preparedness. It should be clear that information security is a serious issue. Definitively, this thesis will consider information security as the process of providing controlled access to information based on proper authorization. A pertinent information security goal is to provide a "multilevel" information security environment

(that is, an environment where multiple levels of sensitive information and user accessibility to that information exist together in a manner such that security is not compromised). The key to achieving computer security lies with the concept of the "security kernel". A discussion of this concept and some supporting definitions is provided in the next section.

a. Basic Security Principles

The protection of secure information in computer systems is affected through two types of control: (1) external controls -- where physical means are used to securely isolate the computer system (e.g., an armed guard) and (2) internal controls -- where the computer itself provides protection by distinguishing information security levels and user accesibilities. Although the discussion in this thesis centers around internal controls, external controls are also a viable and important aspect of the SASS (and other computer system's) information security. As previously stated, the key (or answer) to computer security lies in the security kernel concept. Schell [11] provides a detailed development of the theory behind this concept. The security kernel is defined as that part of the computer system's hardware and software which enforces the authorized access relationships between the user/process (subject) and the accessed information (segment or object).

An important aspect to the development of a secure kernel based system is the security policy to be

enforced. There are two distinct aspects of security policy. The first is the non-discretionary (mandatory) policy that externally constrains what access is permissable; this policy is manifested and implemented in an arrangement where information in the form of a segment (called an "object") is labelled as to its sensitivity; the same is done with the party requesting access (the user/process, called a "subject"). The relationship between the subject and object "labels" that leads to an access permission or denial is defined by a lattice structure [3]. This lattice structure concept will be discussed in the next section. The second aspect of security policy is the discretionary policy, which is a refinement within the non-discretionary constraints. It is emphasized that discretionary security is contained within (and in no way substitutes for) non-discretionary security. An example is the "need to know" policy of the DoD. Implementation of the discretionary security policy for SASS is accomplished in the Supervisor through the maintenance of an Access Control List (ACL) for each file in the file hierarchy. Each access attempt to a file is checked against the ACL and access is granted in accordance with that check and the non-discretionary security check (whichever granted the least access). This allows the users to specify (subject to non-discretionary security constraints) who may access their files. Since the implementation of the discretionary security policy is not a

part of this thesis, a detailed discussion is not provided. Parks [7] provides a discretionary security policy design for SASS.

Implementation of a security policy requires an awareness of and consideration for several basic security properties which are briefly defined below.

The Simple Security Condition restricts a subject's read access to objects whose classification is equal to or less than than the subject's classification (the term classification will hereafter be used to indicate a degree of sensitivity or security importance).

The Confinement Property (or "*-property") restricts a subject's write access to objects whose classification is equal to or greater than the subject's classification. This property prevents a subject from writing to an object of lower classification where another subject (of less than the original subject's classification) would have potential access thus violating security.

The Compatibility property has as a basis the hierarchial structure of the objects (segments) of SASS. The objects of SASS are hierarchially organized in a tree structure. The structure consists of nodes, leaves, and a root from which the tree eminates. A node (an alias table that contains a list of attributes for segments) is directly associated with a segment that is the "mentor" for one or more segments. A leaf, viz., a segment, is not an alias

table but may be a mentor segment (with the same access class as the alias table). The Compatibility property basically states that the object access classification must be non-decreasing in moving from the root down the hierarchy (viz., the access classification of a child must be greater than or equal to its parent).

b. Lattice Model Abstraction

A lattice model of secure information flow concept (discussed by Denning [3]) permits concise formulations of the security requirements of different systems and facilitates the construction of mechanisms that enforce security. Specifically, the relationship between classifications can be represented by a partially ordered lattice structure (examples illustrating this concept are presented in the next section). Authorizations for access (or decisions on compatibilty) then are based on this lattice. With the properties previously discussed as a basis, the accesses permitted are defined below ("sac" is the abbreviation for "subject access classification" and "oac" for "object access classification" and "¦" denotes "not related"):

1. sac = oac, read/write permitted
2. sac > oac, read permitted
3. sac < oac, write permitted
4. sac ¦ oac, no access permitted

Case 3 represents a subject's ability to "write up", which is a capability not supported in SASS; thus for SASS, case 3 is more accurately represented as:

3. sac < oac, no access permitted

At this point, no design detail has been provided for the representation of a classification or for defining how two classifications are compared and determined to be "equal", "greater than", "less than", or "unrelated" (viz., what does sac>oac mean?). The next section will illustrate these ideas both generally and by examples.

c. Examples

Based on military influence, the examples provided are reflective of a subset of the DoD non-discretionary security policy. A classification (or label) is defined to have two parts: (1) a level (e.g., top secret, secret, confidential, or unclassified in the example) and a category (e.g. Crypto (Cy), Nato (N), Nuclear (Nu), or empty (%) in the example). In the actual implementation (chapter III), provisions will be made for eight levels and sixteen categories. (In some reference texts, levels are called categories and categories are called compartments). The levels are defined by a "totally ordered" relationship where all levels are related:

Top Secret > Secret > Confidential > Unclassified

or

TS > S > C > U

The categories are defined as "disjoint" (no relationship exists when comparing individual categories with other individual categories). The classifications (labels) (the concatenation of level with category) then are defined to have a "partially ordered" relationship since some but not all classifications are related. The cases to be illustrated will be illustrated through a general case and then by specific examples. The general structure is defined by:

Subject's classification = (LS, {CS})

Object's classification = (LO, {CO})

where:

LS = Subject's level

{CS} = Subject's set of categories

LO = Object's level

{CO} = Object's set of categories

The non-inclusive set of partially ordered examples will be chosen from a subset of the classifications derivable from the set of totally ordered levels and the set of disjoint categories:

{TS,S,C,U} and {Cy,N,Nu,%}

Case I : Equal (sac =oac)

General - LS = LO and {CS} = {CO}

Examples - (TS,{Cy,N}) = (TS,{Cy,N})

- (U, {Cy}) = (U ,{Cy})

Access - Read/Write

Case II: Greater than (sac > oac)

(1) General - LS > LO and {CO} subset to {CS}

Examples - (S,{N,Nu}) > (C,{N})

- (S,{N,Nu}) > (U,{%})

(2) General - LS > LO and {CS} = {CO}

Examples - (TS,{%}) > (S,{%})

- (S, {Nu,N}) > (U,{Nu,N})

(3) General - LS = LO and {CO} proper subset to {CS}

Examples - (U, {Nu}) > (U,{%})

(TS,{Cy,N,Nu}) > (TS,{Cy})

Access - Read

Case III: Less than (sac < oac)

(1) General - LS < LO and {CS} subset to {CO}

Examples - (S, {%}) < (TS,{N})

- (U, {N,Nu}) < (C, {Cy,N,Nu})

(2) General - LS < LO and {CS} = {CO}

Examples - (S, {%}) < (TS,{%})

- (U, {N,Nu}) < (C, {N,Nu})

(3) General - LS = LO and {CS} proper subset to {CO}

Examples - (U, {%}) < (U, {N})

- (C, {N,Cy}) < (C,{N,Nu,Cy})

Access = no access (in SASS)

= Write (in principle)

Case IV : Unrelated (sac ¦ oac)

(1) General - LS <,>,or = LO and {CS} ¦ {CO}

Examples - (S, {N}) ¦ (C, {Nu})

- (C, {Nu}) ¦ (S, {N })

- (TS,{N}) ¦ (TS,{Cy})

(2) General - LS > LO and {CS} proper subset to {CO}

Examples - (TS,{%}) ¦ (S, {N})

- (C, {N,Nu}) ¦ (U,{N,Nu,Cy})

Explanation - there is a contradiction between the relationship of the levels and the relationship of the categories. Since this contradiction is unresolvable, the classification relationship must be "unrelated".

(3) General - LS < LO and {CO} proper subset to {CS}

Examples - (S, {N,Nu}) ¦ (TS, {N})

- (U, {Cy}) ¦ (C, {%})

Explanation - same as above

Access = No access

d. Applications to the SASS

The cases above are designed to identify each possible relationship that exists between two labels. In the SASS, it is necessary only to identify cases I and II (label 1 >= label 2), while lumping the other cases into a single case which represents "no access". This arrangement encompasses enforcement of the Confinement Property, Simple Security Condition, and the Compatibility property. Enforcement must occur on every access attempt of an object.

A discussion of the implementation of non-discretionary security policy is provided in the next chapter.

B. SEGMENT MANAGER

1. Function

The Segment Manager is the focal point of the segment management function. Using the per-process Known Segment Table as its database and the Memory Manager and Non-Discretionary Security Module in strongly supportive roles, it is responsible for managing the segmented virtual memory for a process. Its role can be viewed as somewhat intermediary in nature (viz., between the Supervisor modules and the Memory Manager modules). The extended instruction set created in the Segment Manager includes the following instructions: CREATE_SEGMENT, DELETE_SEGMENT, MAKE_KNOWN, TERMINATE , SM_SWAP_IN, and SM_SWAP_OUT (note that the names for SWAP_IN and SWAP_OUT have been modified by preceding each with SM_; this is strictly for clarity because the Memory Manager also creates two instructions called SWAP_IN and SWAP_OUT). These instructions are invoked by the Supervisor domain of the process (viz., calls are made from the Supervisor domain via the Gatekeeper to the Segment Manager in the Kernel domain) to provide SASS support to the Host.

In general, when the Segment Manager receives these calls, it performs certain checks to ensure the validity and

security compliance (when required) of the request (call). These checks are performed using its own database (the KST) and by calls to the Non-Discretionary Security Module (when required). The Segment Manager invokes one of six Memory Manager (more specifically, the Distributed Memory Manager Module) created instructions. These instructions include: MM_CREATE_ENTRY, MM_DELETE_ENTRY, MM_ACTIVATE, MM_DEACTIVATE, MM_SWAP_IN, and MM_SWAP_OUT. These invoked instructions (procedures) in turn perform interprocess communciations with the non-distributed memory manager process (where actual memory management functions are accomplished). These interprocess invocations and returns are accomplished through the use of the IPC primitives Signal and Wait. The Segment Manager returns the required arguments to the Supervisor by value (as passed back to it by the Memory Manager and/or determined within itself). The Segment Manager performs actual segment number assignment when a segment is made known to a process' address space. It also performs any further database (KST) updating as may be required. A more detailed description of the specifics of the actions of the Segment Manager will be provided in the implementation described in Chapter III.

2. Database

The Known Segment Table (KST) is the database used to manage segments. The KST is described in its tabular form and PLZ/SYS structured representation in figure 6. There are several basic and pertinent facts to be noted of the KST:

1. It is a process local database; that is, each process has its own KST.
2. The KST is indexed by segment number; each record of the KST consists of a set of fields (description information) regarding a particular segment.
3. Entering information into the fields of a segment is called "making a segment known". This simply refers to adding a segment to a process' address space (viz., making a segment accessible to a process).
4. In SASS, a correspondence exists between making a segment "known" and making a segment "active"; i.e., when a segment is added to the address space of a process, this action results in an entry in the KST (making "known") by the Segment Manager and an entry in the Global Active Segment Table (G_AST) by the Memory Manager process (making it "active"). The G_AST will be described later in this chapter.

A proper description of the structure and fields of the KST is necessary at this point. Using the representation of the PLZ/SYS language structure, the KST is described as an array

of records of fields of varying types. The fields are described separately below. Although the KST index is not in itself a field in the record, it does perform a rather significant role. The KST index is an integer closely related to the segment number of the segment described in that KST entry (viz., it is the subscript into the array of records). This segment number also corresponds to the MMU descriptor register (number) for that segment.

The MM_Handle is the first field in a KST record. The MM_Handle is a system wide unique number that is assigned to each segment with an entry in the G_AST (viz., every active segment). This "handle" is the instrument of controlled single copy sharing of information (segments). It allows a segment to exist under one unique handle but be accessible in the address space of more than one process (with different segment numbers in each address space). The MM_Handle is returned to the Segment Manager by the Memory Manager during the execution of the Make_Known instruction.

The Size field is an integer value (of language structure type "word") which represents the number of 256 byte blocks composing a segment.

The Access_Mode field is used to describe the process' access to the segment (i.e., null or read and/or write).

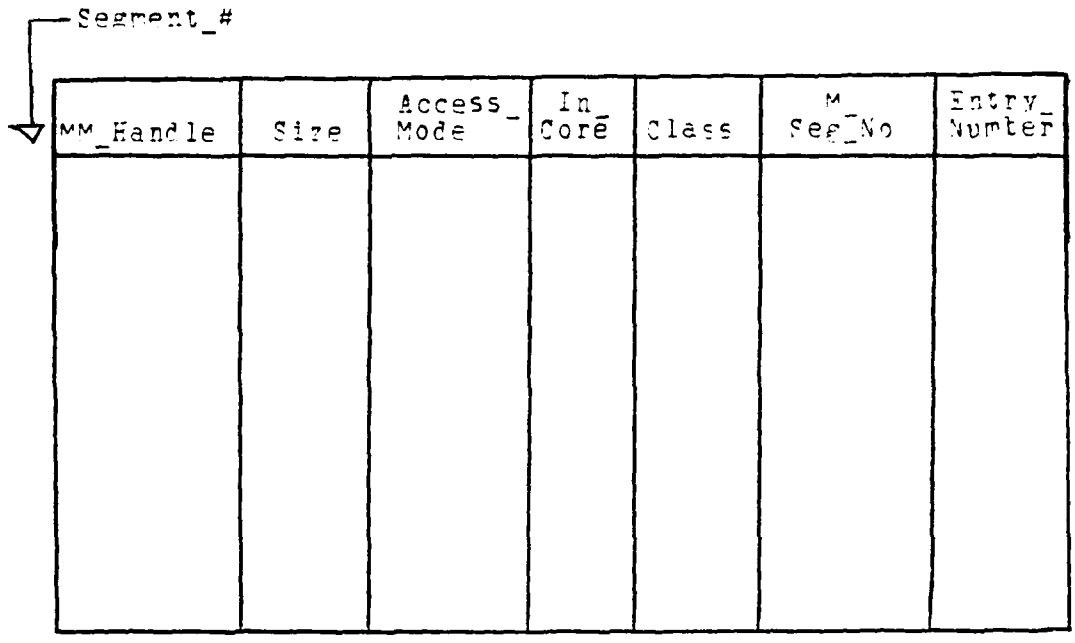
The In_Core field is used to indicate if the segment is or is not in main memory (i.e., this field is a flag or true/false boolean switch).

The Class field is a long word field used to represent the degree of information sensitivity (viz., access class) assigned to the segment. This field (for example) would be used to numerically describe a classification label (as described above).

The Mentor_Seg_Nr field is a number representing the segment number of a segment's parent or "mentor" segment. Its importance will discussed shortly.

The Entry_Nr field is a number representing a segment's index number into its parent or mentor segment's Alias Table (not yet discussed).

The Alias Table is a Memory Manager database and will be described later. The aliasing scheme provided via the alias tables is used to prevent passing system wide information out of the Kernel (i.e., the Unique_ID of a segment). The "alias" of a segment is the concatenation of the Mentor_Seg_Nr with the segment's Entry_Nr (index) into the mentor segment's Alias Table. It is clear that the last two fields of a KST record are the "alias" of that segment.




```
KST    Array [64   KST_REC]

KST_REC   Record [MM_Handle  Array  [3 Word]
                  Size         Word
                  Access_Mode  Byte
                  In_Core      Byte
                  Class        Long
                  M_Seg_No     Short_Integer
                  Entry_Number Short_Integer]
```

Figure 6. Known Segment Table.

C. NON-DISCRETIONARY SECURITY MODULE

The key in protection of secure information using internal controls was identified as the security kernel concept. The basic idea within this concept is to prove the hardware part of the Kernel correct and, similarly, to keep the software part small enough so that proving it correct is feasible. A central component of the kernel software is the Non-Discretionary Security Module (hereafter referred to as the NDS Module). The NDS Module is concerned only with the non-discretionary aspect of the security policy in effect; since the discretionary aspect is subservient in nature to the non-discretionary aspect, it is then sufficient that the Kernel contain only the software representing the non-discretionary aspect of the security policy. The discretionary security is provided outside the kernel in the SASS supervisor. Every attempt to access information must result in an invocation of the NDS Module.

The function of the NDS Module is to compare two classifications (viz., compare two labels), make a decision as to their relationship (i.e., =,>,<,|), and return a true/false interpretive answer relative to the query of the calling procedure. The mechanism used as a basis is the lattice model abstraction previously discussed. The NDS Module does not require a database since the labels it compares are stored in (passed from) other Kernel databases.

D. MEMORY MANAGER

1. Function

The Memory Manager process is the only component of the non-distributed kernel. It is responsible for managing the real memory resources of the system -- main (local and global) memory and secondary storage. It is tasked by other processes within the Kernel domain (via Signal and Wait) to perform memory management functions. This thesis will address the Memory Manager in terms of two components: (1) the Memory Manager Process (also called the nondistributed kernel and the Memory Manager Module), and (2) the distributed Memory Manager (also called the Distributed Memory Manager Module). The former is the "true" memory manager while the latter is the interface with other processes, that is, it resolves the issue of interprocess communication with the "true" memory manager.

The Distributed Memory Manager Module creates the following extended instruction set: MM_CREATE_ENTRY, MM_DELETE_ENTRY, MM_ACTIVATE, MM_DEACTIVATE, MM_SWAP_IN, and MM_SWAP_OUT. The instructions form the mechanism of communication between the Segment Manager of a process and a memory manager process (where the actual memory management functions are performed). The Memory Manager Process instruction set corresponds one to one with that of the Distributed Memory Manager; the set consists of: CREATE_ENTRY, DELETE_ENTRY, ACTIVATE, DEACTIVATE, SWAP_IN,

and SWAP_OUT. The basic functions performed by the Memory manager are allocation/deallocation of global and local memory and of secondary storage, and segment transfers from local to global memory (and vice-versa) and from secondary storage to main memory (and vice-versa).

2. Databases

A detailed and descriptive discussion of the Memory Manager databases is presented in the work of Gary and Moore [4] and the reader may refer to it for memory manager database details. This thesis addresses the implementation of the distributed Memory Manager but not the Memory Manager Process, thus brief descriptions are provided of the latter's databases.

The Global Active Segment Table (G_AST) is a system wide (i.e., shared by all memory manager processes) database used to manage all active segments. A lock/unlock mechanism is used to prevent race conditions from occurring. The distributed memory manager of the signalling process locks the G_AST before it signals the memory manager process.

The Local Active Segment Table (L_AST) is a processor local database which contains an entry for each segment active in a process currently loaded in local memory.

The Alias Table is a system wide database associated with each nonleaf segment in the Kernel. It is a product of the aliasing scheme used to prevent passing system wide

information out of the Kernel. The alias table header (provided for file system reconstruction after system crashes) has two pointers, one linking the alias table to its associated segment, the other linking the alias table to the mentor segment's alias table. The fields in the alias table are Unique_ID, Size, Class, Page_Table_Loc, and Alias_Table_Loc. The index into the alias table is Entry_No.

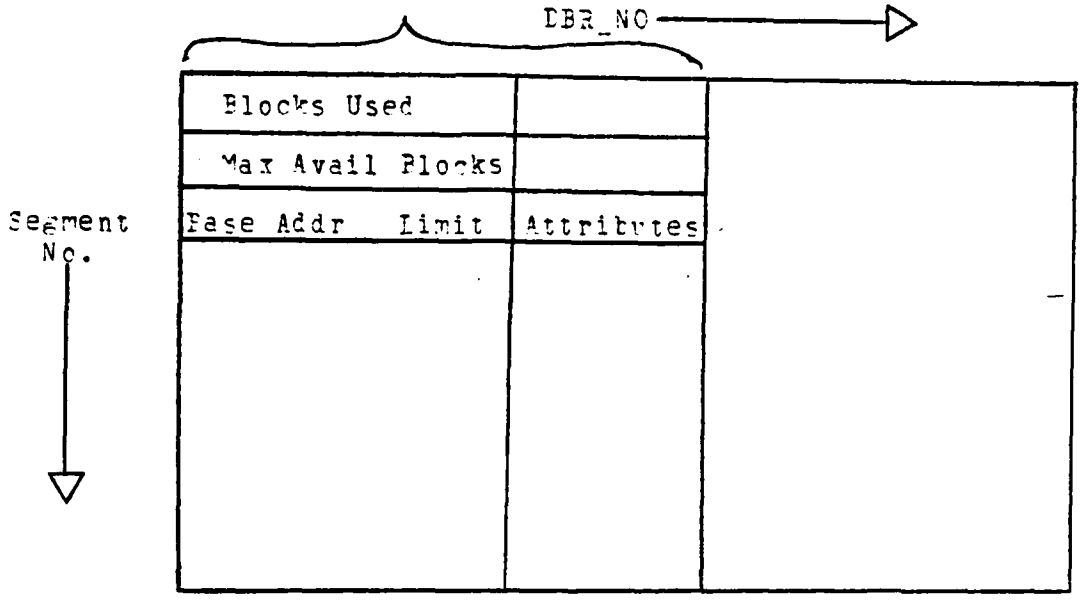
The Memory Management Unit Image (MMU_Image, figure 7) is a processor local database indexed by DBR_No (viz., for each DBR_No there is a MMU_Image record, with each record containing a software image of the segment descriptor registers of the hardware MMU). The MMU_Image is an exact image of the MMU. Each record is indexed by Segment_No (segment number) and each Segment_No entry contains three fields. The Base_Addr field contains the segment's base address in memory. The Limit field contains the number of blocks of contiguous storage for the segment (zero indicates one block). The Attributes field contains 8 flags including 5 which relate to the memory manager. The Blks_Used field and the Max_Blks (available) fields are per record (not per segment entry) and are used in the management of each process' virtual core.

The Memory Bit Maps (Disk_Bit_Map, Global_Memory_Bit_Map, and Local_Memory_Bit_Map) are memory block usage maps that use true/false flags (bits) to indicate the use or availability of storage blocks.

The only database in the Distributed Memory Manager is the Memory Manager CPU Table. It is an array of memory manager VP_ID's (MM_VP_ID) indexed by CPU number. This table enables a signalling process to identify the appropriate memory manager process (virtual processor) to signal.

E. SUMMARY

The segment management functions and key related concepts (such as segmentation) were discussed in this chapter. The importance of segmentation to data sharing and information security was emphasized as were key information security concepts. With this background, the implementation of segment management and a non-discretionary security policy will be described in Chapter III.




```
MMU_Image       Array  [Max_DBR_No    MMU]
MMU             Record [SDR     Array [No_Seg_Desc_Reg
                                       Seg_Desc_Reg]
                        Blks_Used  Word
                        Max_Blks   Word]
Seg_Desc_Reg    Record [Base_Addr  Address
                        Limit      Byte
                        Attributes Byte]
Address         Word
```

Figure 7. Memory Management Unit Image

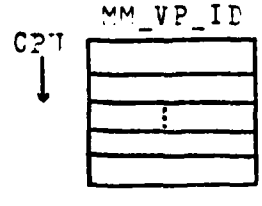


Figure 8. Memory Manager-CPU Table

III. SEGMENT MANAGEMENT IMPLEMENTATION

The implementation of segment management functions and a non-discretionary security policy is presented in this chapter. Paramount to this implementation were several key issues that affected the implementation. These issues are discussed first. The implementation is discussed in terms of the Segment Manager, Non-Discretionary Security (NDS), and Distributed Memory Manager modules.

A. IMPLEMENTATION ISSUES

Segment management for the SASS was provided through the implementation of the Segment Manager Module, the NDS Module, and the Distributed Memory Manager Module. Additionally, since a demonstration/testbed was integral to the testing and verification of the implementation, it was necessary to complete other supportive tasks. Reitz [9] provided a demonstration of the operation of the Inner Traffic Controller primitives SIGNAL and WAIT (for interprocess communication). Integral to this demonstration was the correct performance of the Inner Traffic Controller VP scheduling mechanism and a "stub" of the Traffic Controller and its process scheduling mechanism (the TC support and use of the mechanism of eventcounts and sequencers was not a part of the demonstration). The Segment management demonstration (hereafter referred to as

"Seg_Mgr.Demo") was "built on top of" Reitz' ITC synchronization primitive demonstration (hereafter referred to as "Sync. Demo"). Thus, an immediate issue was to resolve the feasibility of adding on to Sync.Demo and also to refine the present design of the Sync. Demo to facilitate its integration into the Seg_Mgr.Demo. One aspect of this effort was in resolving the problem of how to pass (i.e., in interprocess communication) a larger message.

1. Interprocess Messages

The Sync.Demo passed "word" (16 bit) messages. To provide the mechanism for the distributed memory manager to signal the memory manager process with a command function identification code and the arguments needed to perform that function (e.g., CREATE-ENTRY and its input arguments), a message size of at least eight words (16 bytes) was necessary. An obvious answer was to signal with an array of eight words as the message. PLZ/SYS, however, does not allow passing arrays in its procedure calls (a procedure call is analogous to a subroutine call). Another alternative was to signal with a pointer to the array of words, since PLZ/SYS does allow passing pointers in procedure calls (thus the message would be a pointer to the real message). This, however, would be invalid in the segmented implementation (on the 28000 segmented microprocessor) since identical segment numbers in different processes may not refer to identical segments. For example, a pointer in a process

(e.g., file management) points to an array (i.e., provides its address) by segment number and offset; passing this pointer to another process (e.g., memory manager) would provide this same segment number and offset which, of course, may be a different object in the second process's address space).

Another alternative considered was that of a shared "Mailbox" segment with an associated eventcount acted on by the Kernel Inner Traffic Controller primitives TICKET,ADVANCE and AWAIT. A design for using this concept in the supervisor ring is provided by Parks [7]. This alternative was not deeply considered since these primitives are not included in the current Inner Traffic Controller.

The method ultimately used to signal the new length messages is based on the fact that the ITC is in both the signalling and the receiving (memory manager) processes' address space. The message is loaded into an array in process #1 and a pointer to the array is passed in the call SIGNAL; the VPT, the ITC's database, is then updated by (using the pointer) putting the message into its MSG_Q section. The message is retrieved by process #2 by execution of Reitz' WAIT primitive with only one refinement. That refinement is for the "waiting" process to provide as an argument (in the WAIT primitive) a pointer to its own message array so that the message in the VPT can be copied to it.

This refinement provides for passing a long message essentially "by value" between processes.

2. Structures as Arguments

Another issue concerned the use of pointers in the implementation of segment management. This necessary "evil" is a result of the need to pass linguistically "complex" data types in procedure calls. Complex types refer to array and record structures in PLZ/SYS (as opposed to the "simple" types--byte, word, integer, short-integer, long, and pointer). In managing databases (e.g., KST, G_AST) which consist of arrays of records (which in turn contain records and/or arrays), it was frequently necessary to reference data as an array or record. Within a process, the use of pointers was not a problem (i.e., not a problem such as would be encountered in IPC passing of pointers).

3. Reentrant Code

The issue of code reentrancy was addressed at the assembly language level through the use of a stack segment and registers for storage of local variables. PLZ/SYS (high level language) does not address reentrant procedures and thus the segment management high level code is not automatically reentrant. The problem of reentrancy can be seen by looking at a shared procedure that is not reentrant; such a procedure has storage for its variables allocated statically in memory. Suppose a procedure (e.g., in the Kernel) can be activated by more than one process. While the

procedure is executing in one process, a process switch occurs (e.g., to wait for a disk transfer) and its execution is suspended. The second process is activated, and while it is running it invokes the procedure. While the procedure is executing for the second process it uses the same storage space for variables as it did when executing for the first process. Eventually, it relinquishes the processor. However, when the procedure resumes its execution for the first process, the variable values that were in use by it originally have been changed during its execution in the second process. Thus, incorrect results are now inevitable.

4. Process Structure of the Memory Manager

References to the "Memory Manager" in past works have generally meant the memory manager process (non-distributed kernel). This work references two distinct components of the "memory manager module". The Distributed Memory Manager is an interface provided to the Memory Manager Process. It is, in fact, distributed in the address space of each Supervisor process. In contrast, the Memory Manager Process clearly is not distributed and its address space is contained entirely in the Kernel.

5. Per-Process Known Segment Table

Another key issue was that of the per process Segment Manager database, the KST. Since each process has its own KST, it cannot be linked to the (shared) segment manager procedures. To implement the KST as a per process

database, it was convenient to establish, by convention, a KST segment number that is consistent from process to process. That segment in each process is the KST segment for that process. Implementation is then accomplished by using the segment number to construct a pointer to the base of the appropriate KST. It is then easy to calculate an appropriate offset to index any desired entry in the KST data.

6. DBR Handle

In Reitz's implementation of the multilevel scheduler and the IPC primitives, references to "DBR" (descriptor base register) are references to an address. That address value represents a pointer to an MMU_IMAGE record containing the list of descriptors for segments in the process address space. Gary and Moore [4] reference a "DBR_NO" that is essentially a handle used within the memory manager as an index within the MMU_IMAGE to a particular MMU record. The base address of the MMU record indexed by DBR_NO is then equivalent to the concept of DBR value used in Reitz' work. The effect of this inconsistency on the segment management implementation was minor and will be further discussed later in this chapter.

B. SEGMENT MANAGER MODULE

The Segment Manager Module consists of six procedures representing the six extended instructions it provides. These are based on the design of Coleman [1]. Only calls

from external to the Kernel (via the Gate Keeper) may be made to the Segment Manager (per the loop-free structure of the SASS). The normal sequence of invocation of the Segment Manager functions to allow referencing a segment is: (1) CREATE_SEGMENT--allocate secondary storage for the segment and update the mentor segment's Alias Table, (2) MAKE_KNOWN--add the segment to the process address space (segment number is assigned), (3) SWAP_IN--move the segment from secondary storage into the process's main memory. The normal sequence of invocation to "undo" the above is: (1) SWAP_OUT--move the segment from main memory to secondary storage, (2) TERMINATE--remove the segment from the process's address space, (3) DELETE_SEGMENT--deallocate secondary storage and remove the appropriate entry from the alias table of its mentor segment. The six Supervisor entries into the Segment Manager (viz., the six extended instructions) will be discussed individually below. The PLZ/SYS and PLZ/ASM listings for the Segment Manager are in appendices A and B.

1. Create a Segment

The function that creates a segment (i.e., adds a new segment to the SASS) is CREATE_SEGMENT. This function validates the correctness of the Supervisor call by checking the parameters and making certain security checks. The distributed memory manager is then called to accomplish interprocess communication with the Memory Manager Process,

where segment creation is realized through secondary storage allocation and alias table updating.

CREATE_SEGMENT is passed as arguments: (1) Mentor_Seg_No--the segment number of the mentor segment of the segment to be created, (2) Entry_No--the desired entry number in the alias table of the mentor segment, (3) Class--the access class (label) of the segment to be created, and (4) Size--the desired size of the segment (in blocks of 256 bytes). The initial check is to verify that the desired size does not exceed the designed maximum segment size. If this check is satisfactory, a conversion of the Mentor_Seg_No to a KST index is necessary. This is because the Kernel segments use the first several segment numbers available but do not have entries in the KST. Thus if there were 10 Kernel segments and a system segment had segment number 15, then its index in the KST would actually be 5 (i.e.,the Kernel segments would use numbers 0-9, and this segment would be the sixth segment in the KST and its index would be 5). A call is then made to the procedure ITC_GET_SEG_PTR with the constant KST_SEG_NO passed as a parameter. This procedure will return a pointer to the base of this process' KST. This pointer is then the basis for addressing entries in the KST. The next check is to see if the mentor segment is known (viz., is in the address space of the process, and thus, in the KST). The key to determining if any segment is known is the mentor segment

entry (M_SEG_No) for that segment in the KST. If not known, this entry in the segment's KST record will be filled with the constant NULL_SEG. The basis for checking to see if the segment's mentor segment is known is the aliasing scheme implication that a mentor segment must be known before a segment can be created. The process classification must next be obtained from the Traffic Controller. The process classification is checked to ensure that it is equal to the classification of the mentor segment since write access to its alias table is needed to create a segment. The NDS module's CLASS_EQ procedure is called and returns a code of true or false. The last check is the compatibility check to ensure that the classification of the segment to be created is greater than or equal to the classification of the mentor segment. This is accomplished by calling the NDS Module's CLASS_GE procedure which returns a code of true or false. If any of these checks are unsatisfactory, an appropriate error code is generated and the Segment Manager returns to its calling point. If all checks are satisfactory, then a pointer to the mentor segment's MM_Handle array is derived (HPTR). Note that in the current memory manager design [4] the actual MM_Handle contents are a Unique_ID (a long word, viz., two words concatenated), and an Index_No (index into the G_AST, a word); thus together these two fields are a total of three words. Since the Segment Manager does not interpret this handle, it is considered a three word array

at this level. For this reason, the entire uninterpreted MM_Handle array will be passed by passing its pointer. This pointer and Entry_No, Size, and Class are then passed in a call to the distributed memory manager procedure MM_CREATE_ENTRY. This procedure, in turn, performs IPC with the memory manager process where segment creation ultimately is accomplished. A success code is returned in an IPC message from the memory manager process via the distributed memory manager to the CREATE_SEGMENT procedure to indicate success or failure as appropriate. This success code is checked by the Segment Manager to ensure confinement would not be violated if it is returned to the calling process' supervisor domain. Only after the success code has been returned can the action of segment creation be considered complete. Segment creation does not imply the ability to reference that segment; MAKE_KNOWN will accomplish that.

2. Delete a Segment

The function that deletes a segment (i.e., deletes a segment from SASS) is DELETE_SEGMENT. Validation of parameters and security checks are performed here similar to (but fewer than) the CREATE_SEGMENT checks. The distributed memory manager is then called to cause IPC with the memory manager process, where segment deletion is realized through secondary storage deallocation and alias table entry deletions. DELETE_SEGMENT is passed as arguments: (1) Mentor_Seg_No and (2) Entry_No. Conversion of the

Mentor_Seg_No to a KST index is accomplished first. The pointer to the base of the KST is located and returned, as before. The mentor segment is checked to ensure it is known, again, by verifying that its own M_SEG_No (mentor segment number) entry in the KST is not the NULL_SEG. The process classification is obtained from the TC and checked (by a call to CLASS_EQ) to ensure it is equal to the mentor segment classification, since deleting an entry requires write access to the alias table. If all checks are satisfactory, then the mentor segment's MM_Handle pointer is derived. This pointer and the mentor segment alias table entry number are passed in a call to the distributed menory manager procedure MM_DELETE_ENTRY. It then performs IPC with the memory manager process where segment deletion is accomplished and a success code is returned as before.

3. Make a Segment Known

The function that makes a segment known (i.e., adds that segment to the process' address space by assigning a segment number, updating the KST, and causing the memory manager process to "activate" the segment (that is, add it to the AST)) is MAKE_KNOWN. Making a segment known is the way the Supervisor declares its intention to use a segment. MAKE_KNOWN is passed as arguments: (1) Mentor_Seg_No, (2) Entry_No, and (3) Acess_Desired (e.g., write, read, or null). It returns (1) a success code, (2) the access allowed to the segment, and (3) the segment number. Conversion of

the mentor segment number to a KST index, finding the KST pointer, and verifying that the mentor segment is known occur as previously discussed.

There are three basic cases that may occur in MAKE_KNOWN: (1) the segment is already known (has an entry in the KST), (2) the segment is not known and there is a segment number available, or (3) the segment is not known and there is no segment number available.

A search is made of the KST using each record's (segment's) M_SEG_No (mentor segment number) and Entry_Number fields as the search key. If these two fields match the input values Mentor_Seg_No and Entry_No, then the record indexed is that of the desired segment; thus the segment to be made known is already known. In this case, all that need be done is to return the success code, segment number (converted from the index by adding to it the number of kernel segments), and the access allowed (equal to the Access_Mode entry in the KST for the already known segment).

During the search of the KST, the M_SEG_No field is also checked to see if it contains the NULL_SEG entry (this implies that the segment number associated with the record is "available"). The first time this is noted, the index is saved. Note the first available index is saved since it is desired to assign segment numbers at the "top" of the KST to keep it dense there. When the search does not find that the segment is already known, the index for the available

segment number is retrieved and converted to segment number by adding to it the number of kernel segments. If this index is the NULL_SEG entry, then there is no segment number available. In this event, the success code is set to NO_SEG_AVAIL, the segment number is assigned NULL_SEG, and access allowed is set to NULL_ACCESS (this is the third case mentioned). If the index is not equal to NULL_SEG and conversion to segment number has occurred then the Traffic Controller is called to provide the DBR_No (descriptor base register number) for the current process. The DBR_No is used by the memory manager process as an index in the MMU_Image and the local AST. The distributed memory manager procedure MM_Activate is called; it is passed the DBR number, the pointer to the mentor segment's MM_Handle entry, the mentor segment alias table Entry_No, and the segment number. MM_Activate performs the normal interface function (performs IPC with the memory manager process procedure that updates the local and global AST's) and also updates the KST entry for the new segment's MM_Handle entry (returned from the memory manager process). It also returns to the Segment Manager the success code, the segment classification, and the segment size from the memory manager process. If the success code is "succeeded" then the issue of access to be granted must be resolved. The process classification is obtained from the TC and passed with the segment classification to the NDS Module procedure CLASS_GE. If the

CONDITION_CODE returned is FALSE then access allowed is NULL_ACCESS, the segment number is NULL_SEG, and MM_DEACTIVATE is called to deactivate the segment. An appropriate error code is returned. If it is greater than or equal then the access allowed is assigned as follows: (1) the two classifications are compared again--this time to see if equal; (2) If they are equal, then the access allowed is either read or write per the access desired; (3) if they are not equal (i.e., the process class is greater than the segment class) then the access allowed is read. Finally the KST entries for that segment number (more accurately for its index in the KST) are filled with the appropriate information (e.g., IN_CORE is false, etc.). If the success code returned from the memory manager process via the distributed memory manager is not "succeeded", then the segment number is set to NULL_SEG and the access allowed is set to NULL_ACCESS.

4. Make a Segment Unknown (Terminate)

The function that makes a segment unknown (i.e., removes that segment from the process' address space--by updating the KST and causing the memory manager process to "deactivate" the segment) is TERMIMATE. It results in removal of the M_SEG_No (mentor segment number) entry from that segment's KST record. Terminate is passed the segment number of the segment to be terminated as an argument. It returns a success code. Conversion of the segment number to

a KST index, finding the KST pointer, and verifying that the segment is known occurs in the same manner as previously discussed. The next check is to verify that the segment is not still loaded in the process' virtual core (viz., it has been "swapped-out"). If not, an error code is returned and the user must cause the Segment Manager extended instruction SM_SWAP_OUT to be executed. The next check is to ensure that the user is not attempting to terminate a Kernel segment. The first several segment numbers in a process' address space will be used by Kernel procedures and data (though they will not be entries in the KST). Thus if there were 10 Kernel segments, then the segment number to be terminated must be greater than or equal to #10 (since the Kernel segments used #'s 0-9). Thus a check is made to ensure that the segment number is not less than the number of Kernel segments; otherwise an error code is returned. Next, the segment number is checked to ensure that it is not larger than the maximum segment number allowable (if so, an error code is returned). If all checks are satisfactory, then the segment's MM_Handle pointer and the process DBR_No are obtained (as discussed before) and passed in a call to the MM_Deactivate procedure. It calls the memory manager process procedure DEACTIVATE which removes or updates (as appropriate) the entries in the local and global AST's.

5. Swap a Segment In

The function that swaps a segment from secondary storage to main memory (global or local) is SM_SWAP_IN. It is passed the segment number of the segment to be swapped in as an argument and returns a success code. Conversion of the segment number to a KST index, finding the KST pointer, and verifying that the segment number is known are accomplished as previously discussed. If the check is satisfactory, then the segment's MM_Handle pointer and the process DBR number are obtained. They are passed with the segment's access mode (from the KST) as arguments in the call to MM_SWAP_IN. It performs normal interface (IPC) functions and returns a success code from the memory manager process' SWAP_IN procedure (where, if not already in core, allocation of main memory space and reading the segment into main memory occurs). If the success code is "succeeded" then the segment's IN_CORE entry in the KST is updated to show that the segment is in main memory for this process (i.e., the entry is now "true").

6. Swap a Segment Out

The function that swaps a segment from main memory to secondary storage is SM_SWAP_OUT. It is passed the segment number of the segment to be swapped out as an argument and returns a success code. The behavior of SM_SWAP_OUT is exactly analogous to that of SM_SWAP_IN except that the segment's KST IN_CORE entry is updated to

reflect that the segment has been removed from main memory for this process (i.e., the new entry is "false").

C. NON-DISCRETIONARY SECURITY MODULE

The Non-Discretionary Security Module implements the non-discretionary security policy for the SASS. The NDS module contains two procedures: CLASS_EQ and CLASS_GE; both compare two labels (classifications) and determine if their relationship meets that of the procedure's name (i.e., equal, or greater than or equal). Although the type of checks being made are, in fact, compatibility checks, Simple Security Condition checks, etc, the NDS Module does not recognize or need to recognize this. It simply uses an algorithm to determine if classification #1 = classification #2 or if classification #1 >= classification #2, as appropriate. It then returns a condition code of true or false in accordance with the particular case. The earlier discussion of label comparison in accordance with a partially ordered lattice structure is relevant in discussing the NDS Module's algorithm. Consider the same "totally ordered" relationship TS > S > C > U of levels and the "disjoint" relationship Cy ¦ N ¦ Nu ¦ % of categories. Comparison of levels will be numerical comparisons while comparison of categories will use set theory comparison as a basis. If TS=4, S=3, C=2, U=1 are level numerical assignments, then the totally ordered relationship is

maintained (i.e., TS>S>C>U is still true). Now consider the categories and make the following assignments: Cy=1, N=2, Nu=4, %=0. Note that a classification may have only one level and one category set (the category set may contain several categories). Consider this example: (TS,{Cy,N}. The level is TS (=4). The category is the set {Cy,N} and numerically is formed by performing a logical OR with the categories Cy and N. Sixteen bit representation of this is:

Cy OR N

(0000 0000 0000 0001) OR (0000 0000 0000 0010)

= 0000 0000 0000 0011 = {Cy,N}

If (TS,{Cy,N}) is considered label #1 and (S,{N}) as label #2 then a comparison of the two labels would be:

(1) Compare level #1 with level #2 -- 4 > 3?

Clearly, the answer is yes.

(2) Compare category #1 with category #2 -- is

(0000 0000 0000 0011) a superset of

(0000 0000 0000 0010), or more clearly

is the latter a subset of the former?

The answer is yes, and one way to show that is true is by performing a logical OR of category #1 with category #2 and comparing the result to category #1. If the result of the OR operation equals category #1 then category #1 is a superset (not necessarily proper) of category #2. Since usage of the term subset is more frequent than that of superset, this relationship will typically be stated as

"category #2 is a subset of category #1. To illustrate the above:

{Cy,N} OR {N} :

(0000 0000 0000 0011) OR (0000 0000 0000 0010)

= 0000 0000 0000 0011 = category #1.

This means that, in this example, that category #2 is a subset (not necessarily proper) of category #1. Since level #1 > level #2 and category #2 subset category #1 then label #1 > label #2. Thus, a call to the CLASS_EQ procedure with these two labels as the input classifications would return a condition code of false while CLASS_GE would return true. The decision to have the classifications as long word (32 bits) supports the requirement of some DoD specifications for eight levels and sixteen categories. This module uses sixteen bits for the level and sixteen bits for the category. Appendices E and F are the PLZ/SYS and PLZ/ASM listings for the NDS Module.

1. Equal Classification Check

The CLASS_EQ procedure performs comparison of two classifications (labels) and returns a condition code of true if they are equal (an exact match of the two long words bit per bit) or false if they are not.

2. Greater or Equal Classification Check

The CLASS_GE procedure performs comparison of two classifications (labels) and returns a condition code true if classification #1 is greater than or equal to

classification #2 or a condition code of false otherwise. For classification #1 to be greater than or equal to classification #2, the following must be true: (1) level #1 >= level #2 (determine this by simple numerical comparison of values) and (2) category #2 subset category #1 (determine this by performing a logical OR with the categories and comparing the result to category #1 -- if they are equal then category #2 is a subset of category #1).

Since PLZ/SYS allows passing only "simple" types in calls, the labels were passed as long words (as opposed to each being word arrays of length two). An access class label is never interpreted outside the NDS Module. However, within the NDS Module it is necessary to address the classification's components separately (viz., level and category). Thus, an "overlay" of the logical view of the classification was created. This overlay was a record of type ACCESS_CLASS and it consisted of two fields: level -- 16 bit integer and category -- 16 bit integer. A pointer type CPTR was declared to be of type pointer to ACCESS_CLASS. Two other pointers CLASS1_PTR and CLASS2_PTR were declared to be of type CPTR and were set equal to the base address of CLASS1 and CLASS2 respectively. This "overlay" of the record frame over the two classification labels passed as arguments allowed the desired component addressibility.

Futhermore, the non-discretionary policy enforced by SASS can be changed from the current DoD policy to another lattice policy by changing (only) the NDS Module.

D. DISTRIBUTED MEMORY MANAGER MODULE

The Distributed Memory Manager Module performs as an interface between the Segment Manager and the Memory Manager Process. As its name implies, it is distributed in the kernel domain of each Supervisor process. The key role performed in this module is to arrange and perform interprocess communication between its process (actually the VP) and the memory manager process (VP). The module consists of eight procedures. Six of the procedures are called directly by Segment Manager procedures; they are MM_CREATE_ENTRY, MM_DELETE_ENTRY, MM_ACTIVATE, MM_DEACTIVATE, MM_SWAP_IN, and MM_SWAP_OUT. The other two procedures are "service" procedures called by multiple procedures; they are: MM_GET_DBR_VALUE and PERFORM_IPC. The logic used in the first six procedures is somewhat uniform (except for MM_ACTIVATE). Thus, the general logic will be explained (with MM_CREATE_ENTRY as an example) and it should suffice as a description for all (except MM_ACTIVATE) procedures. The service procedures will be described separately.

1. Description of Procedures

Each procedure is invoked (and returns) on a one to one basis with a corresponding procedure in the Segment

Manager. For example, CREATE_SEGMENT invokes MM_CREATE_ENTRY which signals the CREATE_ENTRY procedure in the Memory Manager Process Module. Associated with each procedure is an IPC message "frame" to describe the unique format of the contents of the message to be signalled to the memory manager process. Similarly, there must be a message "frame" for return messages from the memory manager process; this frame is the same for all but the MM_ACTIVATE procedure. Consider the message frame for MM_CREATE_ENTRY; it consists of: (1) a code to describe which function is to be performed (e.g., CREATE_CODE indicates that the CREATE_ENTRY procedure is the intended recipient of the message), (2) MM_Handle (an array of three words), (3) Entry_No, (4) Size, and (5) Class. The message frame has a filler (in this case) of one byte to ensure that it is of length 16 bytes. The purpose of this frame is to provide an overlay onto the actual message array to be signalled and to facilitate loading the arguments into the message array. This is accomplished by having a pointer of the type that points to the frame but by converting its address so that it actually points to the base of the message array. Consider these lines of PLZ/SYS code:

```
CE_MSGPTR := CE_PTR COM_MSGPTR
CE_MSGPTR^.CREATE_CODE := CREATE_ENTRY_CODE
```

This code is putting a value into the structure pointed to by CE_MSGPTR at entry CREATE_CODE. The key point is that the

frame of that structure is, in fact, CREATE_MSG (as described before), but the physical location pointed to is the message array. This is assured by having the pointer CE_MSGPTR (which points to a structure of type CREATE_MSG) set equal to a pointer (COM_MSGPTR) to the actual message array (COM_MSGBUF). This is accomplished by the first line of code. The message array itself is never directly referenced, but rather the message array that is overlayed by the message frame is filled in the format of the CREATE_MSG frame. In this example, the first two bytes of the message array now contain the value of the constant CREATE_ENTRY_CODE. The remainder of the message array is filled in the same manner (all procedures use the same notion of a frame, although the frames have different formats). The PERFORM_IPC (perform interprocess communication) procedure is called by all procedures at this point in their execution. The key is that the argument passed is the message array pointer not the pointer to the CREATE_MSG record (after all it is only an overlay frame -- linguistically, it is only a type and is never declared as a structure requiring memory storage allocation). When PERFORM_IPC returns, the message array contains a return message. This message consists of only a success code and filler space in all cases but MM_ACTIVATE. Interpretation of the return message is performed in the same manner as loading the message array. The retrieved success code is

returned to the calling Segment Manager procedure. For MM_ACTIVATE, the return message must be interpreted and values for success code, segment size, and segment classification retrieved and returned to the Segment Manager MAKE_KNOWN procedure. The value for the MM_Handle (called the G_AST_Handle by the memory manager process) must be retrieved and entered in the KST record for this segment.

2. Interprocess Communication

The final arrangements and actual performance of IPC is completed by the internal procedure PERFORM_IPC. By locating the identity of the current physical processor (CPU) and using that identity to index into the MM_CPU_TABLE, the VP_ID of the current memory manager is resolved, so that the memory manager process dedicated to this physical processor is signalled. The call to K_LOCK is, in fact, a disguised call to the SPIN_LOCK procedure (since K_LOCK calls SPIN_LOCK). K_LOCK represents an ultimate (as yet unimplemented) goal of a Kernel locking (wait-lock) system. In any event, the G_AST lock must be set prior to signalling the memory manager process. After SIGNAL has been called, a call is made to WAIT with the pointer to the message array as the argument. The synchronization cycle that results is: (1) PERFORM_IPC calls the ITC procedure SIGNAL with the memory manager VP_ID and message array pointer as arguments; PERFORM_IPC then calls WAIT with the message array as the argument, (2) SIGNAL causes the message

array to be copied into the message queue (in the VPT) of the appropriate VP_ID, (3) ultimately, the signalled VP is scheduled; it had previously called WAIT, passing a pointer to its own local message array; the action of WAIT is to copy the message from the VPT to the signalled' process local message array; there it is interpreted by the memory manager process main procedure and the appropriate procedure is called for action (e.g., CREATE_ENTRY), (4) when action is completed the memory manager process fills its local message array with the appropriate return message and calls SIGNAL with a pointer to the message and the original signalling process's VP_ID as arguments, (5) SIGNAL causes the memory manager process' message to be copied into the VPT message queue for the appropriate VP_ID, (6) that VP is eventually scheduled and through the action of WAIT has the return message copied from its message queue in the VPT to its local message array; WAIT then returns to PERFORM_IPC. The G_AST lock is unlocked and PERFORM_IPC returns to the appropriate distributed memory manager procedure.

The last procedure in the distributed memory manager is MM_GET_DBR_VALUE. This procedure simply provides the service of translating a DBR_NO (DBR number) into its appropriate DBR address. It is called by the TC_GETWORK procedure to allow it to call the ITC procedure SWAP_VDBR (remember that presently the Inner Traffic Controller deals with the DBR as the address of the appropriate MMU record in

the MMU_IMAGE while the Traffic Controller uses DBR as a DBR number which indexes to the appropriate MMU record).

E. SUMMARY

The implementation of segment management functions and a non-discretionary security policy for the SASS has been presented in this chapter. The implementation of the Segment Manager Module, Non-Discretionary Security Module, and Distributed Memory Manager management demonstration was described.

Chapter IV will present the conclusions, lessons learned, and suggestions for future work derived from this thesis.

```
9200 EEEE 0000 DDDD DDDD 0000 0040 CCCC CCCC              *..........@....*
9210 0300 0003 0001 0000 0001 0020 CCCC CCCC (FM)         *.......... ....*
9220 0000 0000 0000 CCCC CCCC CCCC CCCC CCCC              *................*
9230 0200 0003 0001 0000 0001 FFFF CCCC CCCC (IO)         *................*
9240 0000 0000 0000 CCCC CCCC CCCC CCCC CCCC              *................*
9250 0000 0003 0001 0000 0002 0060 CCCC CCCC              *...........<....*
9260 0000 0000 0000 CCCC CCCC CCCC CCCC CCCC              *................*
9270 0100 0003 0001 0000 0002 FFFF CCCC CCCC              *................*
9280 0000 0000 0000 CCCC CCCC CCCC CCCC CCCC              *................*
```


Figure 9. Initialized Active Process Table

```
9000 0000 0060 0000 0000 CCCC CCCC CCCC CCCC        *...<.............*
9010 8000 0002 0001 0000 0000 0000 0040 FFFF        *..............@..*
9020 CCCC CCCC CCCC CCCC CCCC CCCC CCCC CCCC        *.................*
9030 8100 0001 0001 FFFF FFFF 0000 0060 FFFF        *..............<..*
9040 CCCC CCCC CCCC CCCC CCCC CCCC CCCC CCCC        *.................*
9050 8100 0001 0001 FFFF FFFF 0000 0020 FFFF        *.............. ..*
9060 CCCC CCCC CCCC CCCC CCCC CCCC CCCC CCCC        *.................*
9070 8100 0000 0000 0000 0000 0000 FFFF FFFF        *.................*
9080 CCCC CCCC CCCC CCCC CCCC CCCC CCCC CCCC        *.................*
9090 EEEE EEEE EEEE EEEE EEEE EEEE EEEE EEEE        *.................*
90A0 FFFF 0020 CCCC CCCC CCCC CCCC CCCC CCCC        *... .............*
90B0 EEEE EEEE EEEE EEEE EEEE EEEE EEEE EEEE        *.................*
90C0 FFFF 0040 CCCC CCCC CCCC CCCC CCCC CCCC        *...@.............*
90D0 EEEE EEEE EEEE EEEE EEEE EEEE EEEE EEEE        *.................*
90E0 FFFF 0060 CCCC CCCC CCCC CCCC CCCC CCCC        *...<.............*
90F0 EEEE EEEE EEEE EEEE EEEE EEEE EEEE EEEE        *.................*
9100 FFFF FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *.................*
```

Figure 10. Initialized Virtual Processor Table

```
[D 9300 18  (FM, partial)
9300 0000 000F 000F 0050 0100 0003 0001 0000        *.......P.........*
9310 0000 0000 0000 0000 0000 0000 0000 FF00        *.................*
9320 0000 0000 0000 0000 0000 0000 0000 FF00        *.................*
[D 9700 18  (IO, partial)
9700 0000 000F 000F 0050 0100 0003 0001 0000        *.......P.........*
9710 0000 0000 0000 0000 0000 0000 0000 FF00        *.................*
9720 0000 0000 0000 0000 0000 0000 0000 FF00        *.................*
[
```


Figure 11. Initialized Known Segment Tables

```
]D 8000 10  (MM, partial)
8000 cccc cccc 7000 cccc 6000 cccc cccc cccc        *....p...<.......*
8010 cccc cccc cccc cccc cccc cccc cccc cccc        *................*
]D 8100 10  (IDLE, partial)
8100 cccc cccc 7100 cccc 6100 cccc cccc cccc        *....q...a.......*
8110 cccc cccc cccc cccc cccc cccc cccc cccc        *................*
]D 8200 10  (IO, partial)
8200 cccc cccc 7200 cccc 9700 cccc cccc cccc        *....r...........*
8210 cccc cccc cccc cccc cccc cccc cccc cccc        *................*
]D 8300 10  (FM, partial)
8300 cccc cccc 7300 cccc 9300 cccc cccc cccc        *....s...........*
8310 cccc cccc cccc cccc cccc cccc cccc cccc        *................*
]
```

Figure 12. Initialized Memory Management Unit Image

```
ID 7090 30  (MM, partial)
7090 CCCC CCCC FFFF 709A 60C0 0000 0000 0000        *......p.<.......*
70A0 0000 0000 0000 0000 5000 8000 7000 AAAA        *........P...p...*
70B0 6000 AAAA 40A6 709A 0000 FFFF 5000 5000        *<...@.p.....P.P.*
70C0 7094 FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *p...............*
70D0 CCCC CCCC CCCC CCCC CCCC CCCC CCCC CCCC        *................*
70E0 5000 FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *P...............*
ID 7190 30  (IDLE, partial)
7190 CCCC CCCC FFFF 719A 61C0 0000 0000 0000        *......q.a.......*
71A0 0000 0000 0000 0000 5200 8100 7100 AAAA        *........R...q...*
71B0 6100 AAAA 40A6 719A DDDD FFFF 5000 5200        *a...@.q.....P.R.*
71C0 7194 FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *q...............*
71D0 CCCC CCCC CCCC CCCC CCCC CCCC CCCC CCCC        *................*
71E0 5000 FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *P...............*
ID 7290 30  (IO, partial)
7290 CCCC CCCC FFFF 729A 62C0 0000 0000 0000        *......r.b.......*
72A0 0000 0000 0000 0000 5280 8200 7200 AAAA        *........R...r...*
72B0 6200 AAAA 40A6 729A 0001 FFFF 5000 5280        *b...@.r.....P.R.*
72C0 7294 FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *r...............*
72D0 CCCC CCCC CCCC CCCC CCCC CCCC CCCC CCCC        *................*
72E0 5000 FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *P...............*
I

ID 7390 30  (FM, partial)
7390 CCCC CCCC FFFF 739A 63C0 0000 0000 0000        *......s.c.......*
73A0 0000 0000 0000 0000 5400 8300 7300 AAAA        *........T...s...*
73B0 6300 AAAA 40A6 739A 0002 FFFF 5000 5400        *c...@.s.....P.T.*
73C0 7394 FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *s...............*
73D0 CCCC CCCC CCCC CCCC CCCC CCCC CCCC CCCC        *................*
73E0 5000 FFFF CCCC CCCC CCCC CCCC CCCC CCCC        *P...............*
I
```

Figure 13. Initialized Process Stack Segments

```
%ZLINK N=SM8 L=SM8.MAP MM.8 IDLE.8 IO.8 FM.8 TC.8 ITC.8 D MM.1 SM.1 ND SEC.8
PROC DATA = (IDLE DATA IO_DATA FM_DATA D MM DATA MM_DATA)
KER_PROC = (ITC INT PROC ITC GLB PROC TC GLB PROC D_MM PROC SM PROC NDS PROC)
ZLINK N=SM8 L=SM8.MAP MM.8 IDLE.8 IO.8 FM.8 TC.8 ITC.8 D MM.1 SM.1 ND SEC.8 PROC
 DATA = (IDLE DATA IO_DATA FM_DATA D_MM_DATA MM_DATA) KER_PROC = (ITC_INT PROC I
TC_GLB_PROC TC_GLB_PROC D_MM_PROC SM_PROC NDS PROC)
ZLINK 2.01
LINK COMPLETE
%IMAGER SM8 ($=5000 MM_PROC $=5200 IDLE_PROC $=5280 IO PROC $=5400 FM PROC $=560
0 KER PROC $=6200 PROC DATA $=8000 MMU DATA $=9000 ITC DATA $=9200 TC DATA) '500
0 6500  O=SYNC.8
IMAGER SM8 ($=5000 MM_PROC $=5200 IDLE PROC $=5280 IO PROC $=5400 FM PROC $=5600
 KER PROC $=6200 PROC DATA $=8000 MMU DATA $=9000 ITC DATA $=9200 TC DATA) '5000
 6500  O=SYNC.8
IMAGER 2.0
1227 BYTES LOADED
%
```


Figure 14. Linker and Imager Command Lines

```
*
NMI
[LOAD SYNC.8
ENTRY POINT 5000
[LOAD DBR.8
ENTRY POINT 8000
[LOAD SYNC STACK.8
ENTRY POINT 7000
[LOAD SYNC DATA.8
ENTRY POINT 9000
[LOAD KST DATA.8
ENTRY POINT 9300
[R R15
R15 40A0 [71B4
RPC 075E [560E
RFC 5040 [5000
[
```

Figure 15. Load Command Lines and Register Initialization

```
IO: READ COMMAND
-------------------------------------------------------------------------
                          FM: IO = SIGNALLER
                          FM: CALL KERNEL(CREATE)
-------------------------------------------------------------------------
                                                  KERNEL = SIGNALLER(FOR FM)
                                                  MM: CREATE ENTRY
-------------------------------------------------------------------------
                          FM: RETURN FROM KERNEL
-------------------------------------------------------------------------
IO: READ COMMAND
-------------------------------------------------------------------------
                          FM: IO = SIGNALLER
                          FM: CALL KERNEL(MAKE KNOWN)
-------------------------------------------------------------------------
                                                  KERNEL = SIGNALLER(FOR FM)
                                                  MM: ACTIVATE
-------------------------------------------------------------------------
                          FM: RETURN FROM KERNEL
-------------------------------------------------------------------------
                          FM: CALL KERNEL(SWAP IN)
NMI
[
```

Figure 16. Generated Output

```
                                                                    KERNEL = SIGNALLER(FOR FM)
                                                                    MM: SWAP IN
-------------------------------------------------------------------------------
                          FM: RETURN FROM KERNEL
-------------------------------------------------------------------------------
IO: READ COMMAND
-------------------------------------------------------------------------------
IO: CALL KERNEL(MAKE KNOWN)
-------------------------------------------------------------------------------
                                                                    KERNEL = SIGNALLER(FOR IO)
                                                                    MM: ACTIVATE
-------------------------------------------------------------------------------
IO: RETURN FROM KERNEL
-------------------------------------------------------------------------------
IO: CALL KERNEL(SWAP_IN)
-------------------------------------------------------------------------------
                                                                    KERNEL = SIGNALLER(FOR IO)
                                                                    MM: SWAP IN
-------------------------------------------------------------------------------

NMI
[
```

Figure 16. Generated Output (continued)

```
[G
IO: RETURN FROM KERNEL
-------------------------------------------------------------------------------
IO: READ COMMAND
-------------------------------------------------------------------------------
                          FM: IO = SIGNALLER
                          FM: CALL KERNEL(SWAP OUT)
-------------------------------------------------------------------------------
                                                  KERNEL = SIGNALLER(FOR FM)
                                                  MM: SWAP OUT
-------------------------------------------------------------------------------
                          FM: RETURN FROM KERNEL
-------------------------------------------------------------------------------
                          FM: CALL KERNEL(TERMINATE)
-------------------------------------------------------------------------------
                                                  KERNEL = SIGNALLER(FOR FM)
                                                  MM: DEACTIVATE
-------------------------------------------------------------------------------
                          FM: RETURN FROM KERNEL
-------------------------------------------------------------------------------
IO: READ COMMAND

NMI
[
```

Figure 16. Generated Output (continued)

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IMPLEMENTATION OF SEGMENT MANAGEMENT FOR A SECURE ARCHIVAL STOR--ETC(U)
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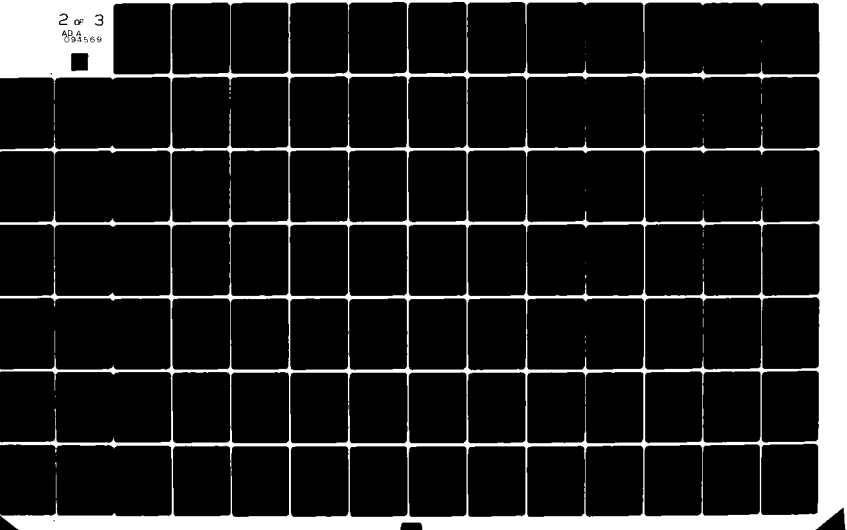
2 OF 3
AD A 094569



```
[G
-------------------------------------------------------------------------
IO: CALL KERNEL(SWAP OUT)
-------------------------------------------------------------------------
                                                KERNEL = SIGNALLER(FOR IO)
                                                MM: SWAP OUT
-------------------------------------------------------------------------
IO: RETURN FROM KERNEL
-------------------------------------------------------------------------
IO: CALL KERNEL(TERMINATE)
-------------------------------------------------------------------------
                                                KERNEL = SIGNALLER(FOR IO)
                                                MM: DEACTIVATE
-------------------------------------------------------------------------
IO: RETURN FROM KERNEL
-------------------------------------------------------------------------
IO: READ COMMAND
-------------------------------------------------------------------------
                          FM: IO = SIGNALLER
                          FM: CALL KERNEL(DELETE)
-------------------------------------------------------------------------
                                                KERNEL = SIGNALLER(FOR FM)
NMI
[
```

Figure 16. Generated Output (continued)

```
[G

                                                    MM: DELETE ENTRY
-------------------------------------------------------------------------------
                          FM: RETURN FROM KERNEL
-------------------------------------------------------------------------------
IO: READ COMMAND
-------------------------------------------------------------------------------
                          FM: IO = SIGNALLER
                          FM: CALL KERNEL(CREATE)
-------------------------------------------------------------------------------
                                                    KERNEL = SIGNALLER(FOR FM

NMI
[
```

Figure 16. Generated Output (continued)

IV. CONCLUSIONS AND FOLLOW ON WORK

The implementation of segment management for the security kernel of a secure archival storage system has been presented. The implementation was completed on Zilog's Z8002 sixteen bit nonsegmented microprocessor. Segmentation hardware (Zilog's Z8010 Memory Management Unit) was not available, therefore it was simulated in software as described by Reitz [9]. The loop free modular construction used in the implementation facilitates ease of expansion or modification.

A non-discretionary security policy was implemented using a partially ordered lattice structure as a basis. Enforcement was realized through an algorithm that compared two labels and determined if their relationship was equal to a desired relationship. Although the DoD security classification system was represented, any non-discretionary security policy that may be represented by a lattice structure may similarly be implemented. This implementation has shown that by having the non-discretionary security policy enforced in one module, changing to another policy requires changing only this one module.

Software engineering techniques used in previous work emphasized the advantages of working with code that is well structured, well documented, and well organized. Despite

being written in assembly language, Reitz' implementation of multiprogramming and process management proved to be consistent in style, clarity and documentation. This enhanced the construction of a segment management demonstration which was built onto his synchronization demonstration. Further, refinements made to his code (not necessitated by any failures of his code) were relatively easily accomplished.

While the segment management implementation appears to perform properly, it has not been subjected to a formal test plan. Such a test plan should be developed and implemented.

The Memory Manager Process has been designed but not implemented. Segment management implementation, provision for IPC using more practical size messages, and the detailed design of the memory manager by Moore and Gary [4], provide a sound foundation for memory manager implementation. A framework of the mainline code needed is provided in the memory manager module of the demonstration code in Appendix I. Prior to this implementation, formal testing of the segment management implementation herein and the monitor implemented by Reitz [9] should be completed.

APPENDIX A - SEGMENT MANAGER PL/SYS LISTINGS

```
SEGMENT_MANAGER             MODULE

CONSTANT
          NULL_ACCESS              := 4
          NULL_SEG                 := -1
          MAX_NO_KST_ENTRIES       := ?? !TO BE DETERMINED!
          MAX_SEG_SIZE             := ?? !TO BE DETERMINED!
          MAX_SEG_NO               := ?? !TO BE DETERMINED!
          KST_SEG_NO               := ?? !TO BE DETERMINED!
          NR_OF_KSEGS              := ?? !TO BE DETERMINED!
          FALSE                    := 0
          TRUE                     := 1
          READ                     := 1
          WRITE                    := 2

! ****     SUCCESS_CODES     **** !
          SUCCEEDED                := 2
          MENTOR_SEG_NOT_KNOWN     := 22
          ACCESS_CLASS_NOT_EQ      := 33
          NOT_COMPATIBLE           := 24
          SEGMENT_TOO_LARGE        := 25
          NO_SEG_AVAIL             := 27
          SEGMENT_NOT_KNOWN        := 28
          SEGMENT_IN_CORE          := 29
          KERNEL_SEGMENT           := 30
          INVALID_SEGMENT_NO       := 31
          NO_ACCESS_PERMITTED      := 32
          LEAF_SEG_EXISTS          := 10
          NO_LEAF_EXISTS           := 11
          ALIAS_DOES_NOT_EXIST     := 23
          NO_CHILD_TO_DELETE       := 20
          G_AST_FULL               := 12
          L_AST_FULL               := 13
          LOCAL_MEMORY_FULL        := 16
          GLOBAL_MEMORY_FULL       := 17
          SEC_STOR_FULL            := 21
          PROC_CLASS_NOT_GE_SEG_CLASS := 41

TYPE      H_ARRAY       ARRAY [ 3       WORD ]

          KST_REC       RECORD [ MM_HANDLE       H_ARRAY
                                 SIZE            WORD
                                 ACCESS_MODE     BYTE
                                 IN_CORE         BYTE
                                 CLASS           LONG
                                 M_SEG_NO        SECRT_INTEGER
                                 ENTRY_NUMBER    SHORT_INTEGER ]

          KST           ARRAY   [ MAX_NO_KST_ENTRIES KST_REC ]
```

```
        KSTPTR      ^KST

        ADDRESS     WORD

        SEG_ARRAY   ARRAY [MAX_SEG_SIZE   BYTE]

EXTERNAL

    CLASS_EQ PROCEDURE
        RETURNS  ( CONDITION_CODE  BYTE ,

    CLASS_GE PROCEDURE
        RETURNS  ( CONDITION_CODE  BYTE )

    MM_CREATE_ENTRY PROCEDURE
        RETURNS  ( SUCCESS_CODE  BYTE )

    MM_DELETE_ENTRY PROCEDURE
        RETURNS  ( SUCCESS_CODE  BYTE ,

    MM_MAKE_KNOWN PROCEDURE
        RETURNS  ( SUCCESS_CODE  BYTE
                   CLASS         LONG
                   SIZE          WORD )

    MM_TERMINATE PROCEDURE
        RETURNS  ( SUCCESS_CODE  BYTE ,

    MM_SWAP_IN PROCEDURE
        RETURNS  ( SUCCESS_CODE  BYTE ,

    MM_SWAP_OUT PROCEDURE
        RETURNS  ( SUCCESS_CODE  BYTE )

    TC_GET_PROC_CLASS PROCEDURE
        RETURNS  ( PROC_CLASS  LONG )

    ITC_GET_SEG_PTR PROCEDURE
        RETURNS  ( SEGPTR  ^SEG_ARRAY )

    MONITOR  PROCEDURE
    !TO BE IMPLEMENTED AT ASSEMBLY LEVEL - SIMPLY WILL
     CALL THE MONITOR AT ADDRESS %059A!

INTERNAL

    HPTR    ^H_ARRAY
    KPTR    KSTPTR
```

```
GLOBAL
!*****************************************************************
*                                                                 *
*     CREATE_SEGMENT PROCEDURE. INVOKED BY SUPERVISOR             *
*     PROCEDURE VIA GATE KEEPER. ENSURES CALL IS VALID            *
*     BY CHECKING TO SEE IF MENTOR SEGMENT KNOWN, IF              *
*     SEGMENT SIZE IS TOO LARGE (DESIGNED MAX SIZE), IF           *
*     ACCESS CLASSIFICATION ARE EQUAL,AND IF COMPATIBILITY        *
*     REQUIREMENTS MET. IF ALL CHECKS ARE SATISFACTORY            *
*     THEN MM_CREATE_ENTRY IS CALLED FOR MEMORY MANAGER           *
*     TO TAKE ACTION.                                             *
*                                                                 *
*****************************************************************!

CREATE_SEGMENT PROCEDURE ( MENTOR_SEG_NO       SHORT_INTEGER
                           ENTRY_NO            SHORT_INTEGER
                           CLASS               LONG
                           SIZE                WORD
                RETURNS    ( SUCCESS_CODE      BYTE )

! **** NOTE:    REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !
LOCAL    M_SEG_INDEX    SHORT_INTEGER
ENTRY
    IF SIZE > MAX_SEG_SIZE THEN
        SUCCESS_CODE := SEGMENT_TOO_LARGE
    ELSE
        M_SEG_INDEX := MENTOR_SEG_NO - NR_OF_KSEGS
        KPTR := KSTPTR ITC_GET_SEG_PTR ( KST_SEG_NO )
        IF KPTR^[M_SEG_INDEX].M_SEG_NO = NULL_SEG THEN
            SUCCESS_CODE := MENTOR_SEG_NOT_KNOWN
        ELSE
            PROC_CLASS := TC_GET_PROC_CLASS
            CONDITION_CODE := CLASS_EQ ( PROC_CLASS,
                                KPTR^[M_SEG_INDEX].CLASS)
            IF CONDITION_CODE = FALSE THEN
                SUCCESS_CODE := ACCESS_CLASS_NOT_EQ
            ELSE
                CONDITION_CODE := CLASS_GE ( CLASS,
                                  KPTR^[M_SEG_INDEX].CLASS )
                IF CONDITION_CODE = FALSE THEN
                    SUCCESS_CODE := NOT_COMPATIBLE
                ELSE
                    EPTR := #KPTR^[M_SEG_INDEX].MM_HANDLE
                    SUCCESS_CODE := MM_CREATE_ENTRY ( EPTR,
                                    ENTRY_NO, SIZE, CLASS )
                    CONFINEMENT_CHECK (SUCCESS_CODE)
                FI
            FI
        FI
    FI
    RETURN
END CREATE_SEGMENT
```

```
!*****************************************************************
*                                                                 *
*     DELETE_SEGMENT PROCEDURE. INVOKED BY SUPERVISOR             *
*     PROCEDURE VIA TPF GATE KEEPER. CHECKS TO SEE IF             *
*     MENTOR SEGMENT KNOWN AND IF ACCESS CLASSIFICATION           *
*     ARE EQUAL. THEN CALLS MM_DELETE_ENTRY FOR MEMORY            *
*     MANAGER ACTION.                                             *
*                                                                 *
*****************************************************************!

DELETE_SEGMENT PROCEDURE  ( MENTOR_SEG_NO     SHORT_INTEGER
                            ENTRY_NO          SHORT_INTEGER)
               RETURNS    ( SUCCESS_CODE      BYTE )

! **** NOTE:   REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL    M_SEG_INDEX    SHORT_INTEGER
ENTRY
    M_SEG_INDEX := MENTOR_SEG_NO - NR_OF_KSEGS
    KPTR := KSTPTR ITC_GET_SEG_PTR ( KST_SEG_NO );
    IF KPTR^[M_SEG_INDEX].M_SEG_NO = NULL_SEG THEN
       SUCCESS_CODE := MENTOR_SEG_NOT_KNOWN
    ELSE
       PROC_CLASS := TC_GET_PROC_CLASS
       CONDITION_CODE := CLASS_EQ ( PROC_CLASS,
                                    KPTR^[M_SEG_INDEX].CLASS    );
       IF CONDITION_CODE = FALSE THEN
          SUCCESS_CODE := ACCESS_CLASS_NOT_EQ
       ELSE
          HPTR := #KPTR^[M_SEG_INDEX].MM_HANDLE
          SUCCESS_CODE := MM_DELETE_ENTRY ( HPTR, ENTRY_NO )
          CONFINEMENT_CHECK (SUCCESS_CODE)
       FI
    FI
    RETURN
END DELETE_SEGMENT
```

```
!*****************************************************************!
*                                                                 *
*     MAKE_KNOWN PROCEDURE. INVOKED BY SUPERVISOR                 *
*     PROCEDURE VIA GATE KEEPER. CHECKS TO SEE IF                 *
*     MENTOR SEGMENT KNOWN. SEARCHES KST TO SEE IF                *
*     SEGMENT ALREADY KNOWN (WHILE ALSO NOTING THE                *
*     FIRST AVAILABLE (UNUSED) SEG #). IF THE SEGMENT             *
*     IS ALREADY KNOWN THEN FINISHED. IF NOT, THEN,               *
*     USING THE AVAILABLE SEG #, CALL MM_ACTIVATE   FOR           *
*     MEMORY MANAGER ACTION. THEN CHECK TO SEE IF ANY             *
*     ACCESS IS ALLOWED. IF YES THEN DETERMINE THE                *
*     APPROPRIATE ACCESS ALLOWED AND UPDATE KST. IF               *
*     NO, THEN RETURN NULL ACCESS.                                *
*                                                                 *
*****************************************************************!

MAKE_KNOWN PROCEDURE  ( MENTOR_SEG_NO    SHORT_INTEGER
                        ENTRY_NO         SHORT_INTEGER
                        ACCESS_DESIRED   BYTE )
           RETURNS    ( SEGMENT_NO      SHORT_INTEGER
                        ACCESS_ALLOWED   BYTE
                        SUCCESS_CODE     BYTE )
! **** NOTE:    REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL
   AVAIL_SEG SHORT_INTEGER
   INDEX     SHORT_INTEGER
   DBR_NO    SHORT_INTEGER
   M_SEG_INDEX     SHORT_INTEGER
ENTRY
   M_SEG_INDEX := MENTOR_SEG_NO - NR_OF_KSEGS
   KPTR := KSTPTR ITC_GET_SEG_PTR ( KST_SEG_NO )
   IF KPTR^[M_SEG_INDEX].M_SEG_NO = NULL_SEG THEN
      SUCCESS_CODE := MENTOR_SEG_NOT_KNOWN
      SEGMENT_NO := NULL_SEG
      ACCESS_ALLOWED := NULL_ACCESS
   ELSE
      PROC_CLASS := TC_GET_PROC_CLASS
      HPTR := #KPTR^[M_SEG_INDEX].MM_HANDLE
      INDEX := 0
      SEGMENT_NO := NULL_SEG
      AVAIL_SEG := NULL_SEG
      SEE_IF_KNOWN:
        DO
        IF KPTR^[INDEX].M_SEG_NO = MENTOR_SEG_NO
        ANDIF KPTR^[INDEX].ENTRY_NUMBER = ENTRY_NO THEN
        !CASE: SEGMENT ALREADY KNOWN!
           SUCCESS_CODE := SUCCEEDED
           SEGMENT_NO := INDEX + NR_OF_KSEGS
           ACCESS_ALLOWED := KPTR^[INDEX].ACCESS_MODE
           EXIT  SEE_IF_KNOWN
```

```
            ELSE
               IF   KPTR^[INDEX].M_SEG_NO = NULL_SEG
               ANDIF AVAIL_SEG = NULL_SEG THEN
                  AVAIL_SEG := INDEX + NR_OF_KSEGS
               FI
               INDEX += 1
               IF INDEX > MAX_NO_KST_ENTRIES THEN EXIT FI
            FI
            OD
         ! EXIT SEE_IF_KNOWN !
         IF SEGMENT_NO = NULL_SEG
         ANDIF AVAIL_SEG <> NULL_SEG THEN  !CASE: SEGMENT NOT
                           KNOWN AND SEG # IS AVAILABLE!
            INDEX := AVAIL_SEG - NR_OF_KSEGS
            SEGMENT_NO := AVAIL_SEG
            DBR_NO := TC_GET_DBR_NO
            SUCCESS_CODE,KPTR^[INDEX].CLASS,KPTR^[INDEX].SIZE:=
               MM_ACTIVATE(DBR_NO,EPTR,ENTRY_NO,SEGMENT_NO)
            CONFINEMENT_CHECK (SUCCESS_CODE)
            IF SUCCESS_CODE = SUCCEEDED THEN
               CONDITION_CODE := CLASS_GE ( PROC_CLASS,
                                            KPTR^[INDEX].CLASS )
               IF CONDITION_CODE = FALSE THEN !NO ACCESS!
                  ACCESS_ALLOWED := NULL_ACCESS
                  SUCCESS_CODE := MM_DEACTIVATE (DBR_NO,EPTR)
                  CONFINEMENT_CHECK (SUCCESS_CODE)
                  SUCCESS_CODE := PROC_CLASS_NOT_GE_SEG_CLASS
                  SEGMENT_NO := NULL_SEG
               ELSE
                  CONDITION_CODE := CLASS_EQ ( PROC_CLASS,
                                               KPTR^[INDEX].CLASS )
                  IF CONDITION_CODE = TRUE
                  ANDIF ACCESS_DESIRED = WRITE THEN
                        ACCESS_ALLOWED := WRITE
                  ELSE
                        ACCESS_ALLOWED := READ
                  FI
                  KPTR^[INDEX].IN_CORE := FALSE
                  KPTR^[INDEX].M_SEG_NO := MENTOR_SEG_NO
                  KPTR^[INDEX].ENTRY_NUMBER := ENTRY_NO
                  KPTR^[INDEX].ACCESS_MODE := ACCESS_ALLOWED
               FI
            ELSE
               SEGMENT_NO := NULL_SEG
               ACCESS_ALLOWED := NULL_ACCESS
            FI
         ELSE
            SUCCESS_CODE := NO_SEG_AVAIL
            SEGMENT_NO := NULL_SEG
            ACCESS_ALLOWED := NULL_ACCESS
         FI
      FI
      RETURN
   END MAKE_KNOWN
```

```
!*****************************************************************************
*                                                                           *
*     TERMINATE PROCEDURE. INVOKED BY  SUPERVISOR                           *
*     PROCEDURE VIA GATE KEEPER. CHECKS TO SEE IF                           *
*     SEGMENT  IS    KNOWN AND IF SEGMENT NUMBER IS                         *
*     VALID. IF CHECKS ARE SATISFACTORY THEN MM_DEACTI-                     *
*     VATE IS CALLED FOR MEMORY MANAGER ACTION.                             *
*                                                                           *
*****************************************************************************!

TERMINATE PROCEDURE  ( SEGMENT_NO   SHORT_INTEGER )
          RETURNS    ( SUCCESS_CODE BYTE )

! ****     NOTE:  REENTRANT PROCEDURE     **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL     INDEX    SHORT_INTEGER
          DBR_NO   SHORT_INTEGER
ENTRY
   INDEX := SEGMENT_NO - NR_OF_KSEGS
   KPTR := KSTPTR_ITC_GET_SEG_PTR ( KST_SEG_NO )
   IF KPTR^[INDEX].M_SEG_NO = NULL_SEG THEN
      SUCCESS_CODE   := SEGMENT_NOT_KNOWN
   ELSE
      IF KPTR^[INDEX].IN_CORE =TRUE THEN
         SUCCESS_CODE := SEGMENT_IN_CORE
      ELSE
         IF SEGMENT_NO < NR_OF_KSEGS
            SUCCESS_CODE := KERNEL_SEGMENT
         ELSE
            IF SEGMENT_NO > MAX_SEG_NO THEN
               SUCCESS_CODE := INVALID_SEGMENT_NO
            ELSE
               HPTR := #KPTR^[INDEX].MM_HANDLE
               DBR_NO := TC_GET_DBR_NO
               SUCCESS_CODE := MM_DEACTIVATE (DBR_NO,HPTR)
               CONFINEMENT_CHECK (SUCCESS_CODE)
               IF SUCCESS_CODE = SUCCEEDED THEN
                  KPTR^[INDEX].M_SEG_NO := NULL
               FI
            FI
         FI
      FI
   FI
   RETURN
END TERMINATE
```

```
!*****************************************************************
*                                                                 *
*    SM_SWAP_IN PROCEDURE. INVOKED BY SUPERVISOR                  *
*    PROCEDURE VIA THE GATE KEEPER. CHECKS TO SEE IF              *
*    SEGMENT KNOWN; IF YES THEN CALLS MM_SWAP_IN FOR              *
*    MEMORY MANAGER ACTION.                                       *
*                                                                 *
*****************************************************************!

SM_SWAP_IN PROCEDURE  ( SEGMENT_NO   SHORT_INTEGER )
           RETURNS    ( SUCCESS_CODE BYTE )

! ****     NOTE:  REENTRANT PROCEDURE     **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL     INDEX     SHORT_INTEGER
          DBR_NO    SHORT_INTEGER
ENTRY
   INDEX := SEGMENT_NO - NF_OF_KSEGS
   KPTR := KSTPTR_ITC_GET_SEG_PTR ( KST_SEG_NO )
   IF KPTR^[INDEX].M_SEG_NO = NULL_SEG THEN
      SUCCESS_CODE    := SEGMENT_NOT_KNOWN
   ELSE
      IF KPTR^[INDEX].IN_CORE = TRUE THEN
         SUCCESS_CODE := SUCCEEDED
      ELSE
         EPTR    := #KPTR^[INDEX].MM_HANDLE
         DBR_NO := TC_GET_DBR_NO
         SUCCESS_CODE    := MM_SWAP_IN ( EPTR, DBR_NO,
                                KPTR^[INDEX].ACCESS_MODE )
         CONFINEMENT_CHECK (SUCCESS_CODE)
         IF   SUCCESS_CODE = SUCCEEDED THEN
            KPTR^[INDEX].IN_CORE := TRUE
         FI
      FI
   FI
   RETURN
END SM_SWAP_IN
```

```
!*****************************************************************
*                                                                 *
*     SM_SWAP_OUT PROCEDURE. INVOKED BY SUPERVISOR                *
*     PROCEDURE VIA THE GATE KEEPER. CHECKS TO SEE IF             *
*     SEGMENT KNOWN; IF YES THEN MM_SWAP_OUT IS CALLED            *
*     FOR MEMORY MANAGER ACTION.                                  *
*                                                                 *
*****************************************************************!

SM_SWAP_OUT PROCEDURE  ( SEGMENT_NO   SHORT_INTEGER )
            RETURNS    ( SUCCESS_CODE BYTE )

! ****     NOTE:  REENTRANT PROCEDURE     **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL     INDEX    SHORT_INTEGER
          DBR_NO   SHORT_INTEGER
ENTRY
   INDEX := SEGMENT_NO - NR_OF_KSEGS
   KPTR := KSTPTR_ITC_GET_SEG_PTR (KST_SEG_NO )
   IF KPTR^[INDEX].M_SEG_NO = NULL_SEG_THEN
      SUCCESS_CODE    := SEGMENT_NOT_KNOWN
   ELSE
      IF KPTR^[INDEX].IN_CORE = FALSE THEN
         SUCCESS_CODE := SUCCEEDED
      ELSE
         HPTR    := #KPTR^[INDEX].MM_HANDLE
         DBR_NO := TC_GET_DBR_NO
         SUCCESS_CODE    := MM_SWAP_OUT ( DBR_NO,HPTR )
         CONFINEMENT_CHECK (SUCCESS_CODE)
         IF SUCCESS_CODE = SUCCEEDED THEN
            KPTR^[INDEX].IN_CORE := FALSE
         FI
      FI
   FI
   RETURN
END SM_SWAP_OUT
```

```
!*****************************************************************************
*                                                                           *
*     CONFINEMENT_CHECK PROCEDURE. SERVICE PROCEDURE TO                     *
*     ENSURE NO SECURITY VIOLATION OCCURS WHEN INFO IS                      *
*     PASSED OUT OF THE KERNEL VIA THE SUCCESS_CODE.                        *
*     CALLS ASSEMBLY PROCEDURE - MONITOR WHICH IS TO                        *
*     CAUSE A JUMP TO THE MONITOR'S ADDRESS %2E9A.                          *
*                                                                           *
*****************************************************************************!

CONFINEMENT_CHECK PROCEDURE  (SUCCESS_CODE  BYTE,

! ****     NOTE:  REENTRANT PROCEDURE     **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

ENTRY
    IF SUCCESS_CODE
            CASE LEAF_SEG_EXISTS THEN
            MONITOR !EXIT SYSTEM!
            CASE NO_LEAF_EXISTS THEN
            MONITOR !EXIT SYSTEM!
            CASE ALIAS_DOES_NOT_EXIST THEN
            MONITOR !EXIT SYSTEM!
            CASE NO_CHILD_TO_DELETE THEN
            MONITOR !EXIT SYSTEM!
            CASE G AST_FULL THEN
            MONITOR !EXIT SYSTEM!
            CASE L AST_FULL THEN
            MONITOR !EXIT SYSTEM!
            CASE LOCAL_MEMORY_FULL THEN
            MONITOR !EXIT SYSTEM!
            CASE GLOBAL_MEMORY_FULL THEN
            MONITOR !EXIT SYSTEM!
            CASE SEG_STOR_FULL THEN
            MONITOR !EXIT SYSTEM!
    FI
    RETURN
END CONFINEMENT_CHECK
END SEGMENT_MANAGER
```

```
!
!     APPENLIX B - SEGMENT MANAGER PLZ/ASM LISTINGS
!
        SEG_MGR             MODULE

        CONSTANT
          NULL_SEG                  := -1
          NULL_ACCESS               := 4
          MAX_SEG_NO                := 64
          MAX_NO_KST_ENTRIES        := 54
          MAX_SEG_SIZE              := 128
          KST_SEG_NO                := 2
          NR_OF_KSEGS               := 10
          TRUE                      := 1
          FALSE                     := 0
          READ                      := 1
          WRITE                     := 0
        ! ****     SUCCESS_CODES      **** !
          SUCCEEDED                 := 2
          MENTOR_SEG_NOT_KNOWN      := 22
          ACCESS_CLASS_NOT_EQ       := 33
          NOT_COMPATIBLE            := 24
          SEGMENT_TOO_LARGE         := 25
          NO_SEG_AVAIL              := 27
          SEGMENT_NOT_KNOWN         := 28
          SEGMENT_IN_CORE           := 29
          KERNEL_SEGMENT            := 30
          INVALID_SEGMENT_NO        := 31
          NO_ACCESS_PERMITTED       := 32
          LEAF_SEG_EXISTS           := 10
          NO_LEAF_EXISTS            := 11
          ALIAS_DOES_NOT_EXIST      := 23
          NO_CHILD_TO_DELETE        := 26
          G_AST_FULL                := 12
          L_AST_FULL                := 13
          PROC_CLASS_NOT_OF_SEG_CLASS :=41
!PAGE
```

```
        LOCAL_MEMORY_FULL       := 16
        GLOBAL_MEMORY_FULL      := 17
        SEC_STOR_FULL           := 21
        MONITOR                 := %059A

      TYPE      H_ARRAY      ARRAY [ 3      WORD ]

                KST_REC      RECORD
                      [ MM_HANDLE      H_ARRAY
                        SIZE           WORD
                        ACCESS_MODE    BYTE
                        IN_CORE        BYTE
                        CLASS          LONG
                        M_SEG_NO       SHORT_INTEGER
                        ENTRY_NUMBER   SHORT_INTEGER]

                ADDRESS      WORD

        SEG_ARRAY     ARRAY [MAX_SEG_SIZE    BYTE]




      INTERNAL

      $SECTION KST_DCL
      !NOTE: THIS SECTION IS AN OVERLAY/FRAME USED TO
       DEFINE THE KST FORMAT. NO STORAGE IS ASSIGNED
       RATHER THE KST IS STORED IN A SEPARATE
       SEGMENT SET ASIDE FOR IT    !
      $ABS 0
2022  KST           ARRAY [MAX_NO_KST_ENTRIES KST_REC]

 !PAGE
```

```
73      EXTERNAL
74
75          CLASS_EQ PROCEDURE
76
77          CLASS_GE PROCEDURE
78
79          MM_CREATE_ENTRY PROCEDURE
80
81          MM_DELETE_ENTRY PROCEDURE
82
83          MM_ACTIVATE PROCEDURE
84
85          MM_DEACTIVATE PROCEDURE
86
87          MM_SWAP_IN PROCEDURE
88
89          MM_SWAP_OUT PROCEDURE
90
91          TC_GET_PROC_CLASS PROCEDURE
92
93          ITC_GET_SEG_PTR PROCEDURE
94
95          TC_GET_DBR_NO PROCEDURE
96
97
98  !PAGE
```

```
!
                          99      $SECTION SM_PROC
                         100      GLOBAL
                         101
0000                     102      CREATE_SEG                    PROCEDURE
                         103
                         104          !*****************************************!
                         105          ! CHECKS VALIDITY OF CREATE REQUEST AND !
                         106          ! CALLS MM_CREATE IF VALID.             !
                         107          !*****************************************!
                         108          ! REGISTER USE:                         !
                         109          !  PARAMETERS                          !
                         110          !  R1: MENTOR_SEG_NO(INPUT)            !
                         111          !  R2: ENTRY_NO(INPUT)                 !
                         112          !  R3: SIZE(INPUT)                     !
                         113          !  RR4: CLASS (INPUT                   !
                         114          !  R0: SUCCESS_CODE (RETURNED)         !
                         115          !  LOCAL USE                           !
                         116          !  R9: KST REC INDEX                   !
                         117          !  R6,R7 VARIOUS USES                  !
                         118          !  R13: ^KST                           !
                         119          !*****************************************!
                         120
                         121      ENTRY
0000 0403  0380          122          CP   R3,#MAX_SEG_SIZE
0004 5E02  0010'         123          IF   GT  THEN
0008 2100  0019          124               LL   R0,#SEGMENT_TOO_LARGE
000C 5E08  03A2'         125          ELSE
0010 030F  000A          126               SUB  R15,#10  !STACK AREA FOR INPUT REGS!
0014 1CF9  0104          127               LDM  @R15,R1,#5
0018 2101  0002          128               LD   R1,#KST_SEG_NO
001C 5F00  0000*         129               CALL ITC_GET_SEG_PTR  !(R1: KST_SEG_NO)!
                         130                                     !(RET:R0: ^KST)!
0020 A10D                131               LD   R13,R0  !KST BASE ADDRESS (IE ^KST)!
0022 1CF1  0104          132               LDM  R1,@R15,#5  !RESTORE NEEDED REGS!
                         133  !PAGE
```

```
                    !
002E A119                   134             LD    R9,R1  !COPY OF MENTOR_SEG_NO!
0028 0309  0004             135             SUB   R9,#NR_OF_KSEGS  !CONVERT MENTOR_SEG_NO
                            136                                    KST REC INDEX!
002C 190E  0010             137             MULT  RR8,#SIZEOF KST_REC !OFFSET TO KST_REC!
0030 819D                   138             ADD   R13,R9  !ADD OFFSET TO KST BASE ADDRESS!
0032 2106  FFFF             139             LD    R6,#NULL_SEG
0036 4ADE  000E             140             CPB   RL6,KST.M_SEG_NO(R13)
003A 5E0E  0046'            141             IF  EQ  THEN  !MENTOR SEG NOT KNOWN!
003E 2100  0016             142                   LD    R0,#MENTOR_SEG_NOT_KNOWN
0042 5E0E  009E'            143             ELSE
0046 93FD                   144                   PUSH  @R15,R13
0048 5F00  0000*            145                   CALL  TC_GET_PROC_CLASS !(RR2:PROC_CLASS)!
004C 97FD                   146                   POP   R13,@R15
004F 54D4  000A             147                   LDL   RR4,KST.CLASS(R13)
0052 93FD                   148                   PUSH  @R15,R13
0054 5F00  0000*            149                   CALL  CLASS_EQ  !(RR2: PROC_CLASS)!
                            150                                   !(RR4: MENTOR SEG CLASS)!
                            151                                   !(R1:(RET)CONDITION_CODE)!
0058 97FD                   152                   POP   R13,@R15
005A A116                   153                   LD    R6,R1
005C 1CF1  0104             154                   LDM   R1,@R15,#5 !RESTORE INPUT REGS!
0060 0B06  0000             155                   CP    R6,#FALSE
0064 5E0E  0070'            156                   IF  EQ  THEN
0068 2100  0021             157                         LD    R0,#ACCESS_CLASS_NOT_EQ
006C 5E0E  009E'            158                   ELSE
                            159
0070 93FD                   160                         PUSH  @R15,R13  !SAVE ^KST!
0072 9442                   161                         LDL   RR2,RR4  !CLASS!
0074 54D4  000A             162                         LDL   RR4,KST.CLASS(R13)
0078 5F00  0000*            163                         CALL  CLASS_GE  !(RR2:CLASS,!
                            164                                         !(RR4:MENTOR CLASS)!
                            165                                         !(RET:R1:COND_CODE)!
007C 97FD                   166                         POP   R13,@R15  !RESTORE PTR!
007E 0B01  0000             167                         CP    R1,#FALSE
0082 1CF1  0104             168                         LDM   R1,@R15,#5
                            169 !PAGE
```

```
                !
0086 5E0E  0092'     170                                IF          EQ  THEN
008A 2100  0018      171                                    LD      R0,#NOT_COMPATIBLE
008E 5E0E  009E'     172                                ELSE
0092 76D1  0000      173                                    LDA     R1,KST.MM_HANDLE(R13)
0096 5F00  0000*     174                                    CALL    MM_CREATE_ENTRY
                     175                                    !(R1:PTR TO MM_HANDLE)!
                     176                                    !(ENTRY_NO)!
                     177                                    !(R3:SIZE)!
                     178                                    !(RR4:CLASS)!
                     179                                    !(R2:(RETURNED)SUCCESS_CODE)!
009A 5F00  041A'     180                                    CALL CONFINEMENT_CHECK
                     181                                      !(R2:SUCCESS_CODE)!
                     182                                FI
                     183                            FI
                     184                        FI
009E 010F  000A      185                        ADD     R15,#10
                     186                    FI
00A2 9E0E            187                    RET
00A4                 188                END CREATE_SEG
                     189 !PAGE
```

```
!
00A4                  DELETE_SEG                              PROCEDURE
                      !*******************************************!
                      !  CHECKS VALIDITY OF DELETE REQUEST AND    !
                      !  CALLS MM_DELETE IF VALID.                !
                      !*******************************************!
                      !  REGISTER USE:                            !
                      !  PARAMETERS                               !
                      !   R1:MENTOR_SEG_NO(INPUT)                 !
                      !   R2:ENTRY_NO(INPUT)                      !
                      !   R0:SUCCESS_CODE(RETURNED)               !
                      !  LOCAL USE                                !
                      !   R6:VARIOUS LOCAL USES                   !
                      !*******************************************!

                      ENTRY
00A4 93F1                 PUSH   @R15,R1   !SAVE NEEDED REGS!
00A6 93F2                 PUSH   @R15,R2
00A8 2101  0002           LD     R1,#KST_SEG_NO
00AC 5F00  0000*          CALL   ITC_GET_SEG_PTR  !R1:KST_SEG_NO!
00B0 A10D                 LD     R13,R0   !^KST!
00B2 97F2                 POP    R2,@R15  !RESTORE INPUT REGS!
00B4 97F1                 POP    R1,@R15
00B6 0301  000A           SUB    R1,#NR_OF_KSEGS  !CONVERT MENTOR_SEG_NO TO
                                                   KST REC INDEX!
00BA 1900  0010           MULT   RR0,#SIZEOF KST_REC  !OFFSET TO DESIRED REC!
00BE 811D                 ADD    R13,R1  !ADD OFFSET TO KST BASE ADDRESS!
00C0 2106  FFFF           LD     R6,#NULL_SEG
00C4 4ADE  000E           CPB    RL6,KST.M_SEG_NO(R13)
00C8 5E0E  00D4'          IF   EQ   THEN  !MENTOR SEGMENT NOT KNOWN!
00CC 2100  0016                  LD     R0,#MENTOR_SEG_NOT_KNOWN
00D0 5E08  010E'          ELSE
00D4 93F1                        PUSH   @R15,R1   !SAVE NEEDED REGS!
00D6 93F2                        PUSH   @R15,R2
00D8 93FD                        PUSH   @R15,R13
                      !PAGE
```

```
                !
00DA 5F00  0000*     225                CALL  TC_GET_PROC_CLASS
                     226                      !(RETURNS RR2:PROC_CLASS)!
00DE 97FD            227                POP   R13,@R15
00E0 54D4  00CA      228                LDL   RR4,KST.CLASS(R13)  !MENTOR SEG CLASS!
00E4 93FD            229                PUSH  @R15,R13
00E6 5F00  0000*     230                CALL  CLASS_EQ  !(RR2:PROCESS CLASS)!
                     231                              !(RR4:MENTOR SEG CLASS)!
                     232                              !(R1:(RET) CONDITION_CODE)!
00EA A116            233                LD    R6,R1
00EC 97FL            234                POP   R13,@R15
00EE 97F2            235                POP   R2,@R15  !RESTORE NEEDED REGS!
00F0 97F1            236                POP   R1,@R15
00F2 0B06  0000      237                CP    R6,#FALSE
00F6 5E0E  0102'     238                IF    EQ   THEN
00FA 2100  0021      239                      LD    R0,#ACCESS_CLASS_NOT_EQ
00FE 5E0E  010E'     240                ELSE
0102 76D1  0000      241                      LDA   R1,KST.MM_HANDLE(R13)
0106 5F00  0000*     242                      CALL  MM_DELETE_ENTRY
                     243                      !(R1:MM_HANDLE)!
                     244                      !(R2:ENTRY_NO)!
                     245                      !(R0:(RET)SUCCESS_CODE)!
010A 5F00  041A'     246                      CALL CONFINEMENT_CHECK
                     247                      !(R0:SUCCESS_CODE)!
                     248                FI
                     249           FI
010E 9E08            250           RET
0110                 251      END DELETE_SEG
                     252 !PAGE
```

```
                                !
0110                            MAKE_KNOWN                      PROCEDURE
                                !*************************************************!
                                !  CHECKS VALIDITY OF MAKE KNOWN REQUEST AND      !
                                !  CALLS MM_ACTIVATE   IF VALID. ASSIGNS SEG      !
                                !  NUMBER AND UPDATES KST.                        !
                                !*************************************************!
                                !  REGISTER USE:                                  !
                                !  PARAMETERS:                                    !
                                !   R1:MENTOR_SEG_NO(INPUT)                       !
                                !   R2:ENTRY_NO(INPUT)                            !
                                !   R3:ACCESS_DESIRED(INPUT)                      !
                                !   R0:SUCCESS_CODE(RET)                          !
                                !   R1:SEGMENT_NO(RET)                            !
                                !   R2:ACCESS_ALLOWED(RET)                        !
                                !  LOCAL USE                                      !
                                !   IDENTIFIED AT POINT OF USAGE                  !
                                !*************************************************!
                                ENTRY
0110 93F1                       PUSH  @R15,R1  !SAVE INPUT REGS!
0112 91F2                       PUSHL @R15,RR2
0114 2101  0002                 LD    R1,#KST_SEG_NO
0118 5F00  0000*                CALL  ITC_GET_SEG_PTR  !(R1:KST_SEG_NO,RET:R0:^KST)!
011C A10D                       LD    R13,R0  !^KST!
011E 95F2                       POPL  RR2,@R15
0120 97F1                       POP   R1,@R15
0122 A115                       LD    R5,R1  !COPY OF MENTOR_SEG_NO!
0124 0305  000A                 SUB   R5,#NR_OF_KSEGS !CONVERT TO INDEX!
0128 1904  0010                 MULT  RR4,#SIZEOF KST_REC !KST OFFSET TO SEG REC!
012C 815D                       ADD   R13,R5  !ADD OFFSET TO ^KST!
012E 2104  FFFF                 LD    R4,#NULL_SEG
0132 4ADC  000E                 CPR   R4,KST.M_SEG_NO(R13)
0136 5F0E  014A'                IF EQ THEN
013A 2103  0016                    LD    R0,#MENTOR_SEG_NOT_KNOWN
013E 2101  FFFF                    LD    R1,#NULL_SEG
                                !PAGE
```

```
!
0142 2102  0004          LD    R2,#NULL_ACCESS
0146 5E08  02BA'      ELSE
014A 2107  0000          LD    R7,#0  !KST INDEX!
014E 2108  FFFF          LD    R8,#NULL_SEG  !AVAIL SEG INDEX!
0152 A109                LD    R9,R0  !^KST!
0154 210A  FFFF          LD    R10,#NULL_SEG !SEG KNOWN INDICATOR!
                         SEE_IF_KNOWN:
                         DO
0158 4A99  000E             CPB   RL1,KST.M_SEG_NO(R9)
015C 5E0E  017C'            IF EQ THEN
0160 4A9A  000F                CPB   RL2,KST.ENTRY_NUMBER(R9)
0164 5E0F  017C'               IF EQ THEN  !CASE: SEG KNOWN!
0168 2100  0002                   LD    R0,#SUCCEEDED
016C 0107  000A                   ADD   R7,#NR_OF_KSEGS
0170 A171                         LD    R1,R7  !SEG#!
0172 609A  0008                   LDB   RL2,KST.ACCESS_MODE(R9)
0176 A11A                         LD    R10,R1  !SET SEG KNOWN INDICATOR!
0178 5E08  01A6'                  EXIT FROM SEE_IF_KNOWN
                               FI
                            FI

017C 4A9C  000E             CPB   RL4,KST.M_SEG_NO(R9) !SEE IF SEG # AVAIL!
0180 5E0F  0192'            IF EQ THEN
0184 0B28  FFFF                CP    R8,#NULL_SEG
0188 5E0E  0192'               IF EQ THEN
018C A178                         LD    R8,R7 !SAVE FIRST AVAIL SEG INDEX!
018E 0108  000A                   ADD   R8,#NR_OF_KSEGS !CONVERT TO SEG #!
                               FI
                            FI
0192 A970                   INC   R7
0194 0109  0010             ADD   R9,#SIZEOF KST_REC !INCREMENT ONE REC!
0198 0B07  0036             CP    R7,#MAX_NO_KST_ENTRIES
019C 5E22  01A4'            IF GT THEN
01A0 5E08  01A6'               EXIT FROM SEE_IF_KNOWN
                      !PAGE
```

```
!
                              FI
01A4 E8D9                  OD
                           !SEE_IF_KNOWN!
01A6 0B0A  FFFF            CP     R10,#NULL_SEG
01AA 5E0E  02BA'           IF EQ THEN  !SEG KNOWN INDICATOR NOT SET!
01AF 0B08  FFFF               CP     R8,#NULL_SEG
01B2 5E06  02AE'              IF NE THEN !CASE:SEG_UNKNOWN AND SEG# AVAIL!
01B6 91F0                        PUSHL @R15,RR0  !^KST AND MENTOR_SEG_NO!
01B8 91F2                        PUSHL @R15,RR2 !ENTRY_NO &ACCESS_DESIRED!
01BA 93F8                        PUSH  @R15,R8 !SEG #!
01BC 93FD                        PUSH  @R15,R13 !MENTOR SEG REC PTR!
01BE 5F00  0000*                 CALL  TC_GET_DBR_NO  !(RET:RL1:DBR_NO)!
01C2 A11A                        LD    R10,R1  !DBR_NO!
01C4 97FD                        POP   R13,@R15
01C6 97F8                        POP   R8,@R15
01C8 95F2                        POPL  RR2,@R15
01CA 95F0                        POPL  RR0,@R15
                                 !MUST REARRANGE REGS FOR PASSING AND
                                  RETURN CONSISTENCY OF LOCATION!
01CC A135                        LD    R5,R3  !ACCESS_DESIRED!
01CE A123                        LD    R3,R2  !ENTRY_NO!
01D0 76D2  0000                  LDA   R2,KST.MM_HANDLE(R13) !MENTOR HPTR!
01D4 A116                        LD    R6,R1  !MENTOR_SEG_NO!
01D6 A181                        LD    R1,R8  !SEGMENT_NO (SAVE)!
01D8 A184                        LD    R4,R8  !SEGMENT_NO (PASSING ARG)!
01DA A109                        LD    R9,R0  !^KST!
01DC 030F  0014                  SUB   R15,#20
01E0 1CF9  0109                  LDM   @R15,R1,#10 !SAVE REGS 1-10!
01E4 A1A1                        LD    R1,R10  !DBR_NO PASSED IN R1!
01E6 5F00  0000*                 CALL  MM_ACTIVATE
                                 !(R1:DBR_NO,R2:HPTR,R3:ENTRY_NO,
                                  R4:SEGMENT_NO)!
                                 !(RET:R0:SUCCESS_CODE,RR2:CLASS,R4:SIZE)!
01FA 5F00  041A'                 CALL  CONFINEMENT_CHECK !(R0:SUCCESS_CODE)!
01FE 942A                        LDL   RR10,RR2  !CLASS!
                 !PAGE
```

```
!
01F6 A14C                359
01F8 1CF1  0102          360
01FA A187                361
01FE 0307  000A          362
01FC 1926  0010          363
0200 A17D                364
0202 619D                365
0204 5DDA  003A          366
0206 6FLC  0006          367
020C 0A06  0202          368
0210 5E0E  029E'         369
0214 93FD                370
0216 5F00  0000*         371
                         372
021A 97FD                373
021C 54D4  000A          374
0220 93FD                375
0222 91F2                376
0224 91F4                377
0226 5F00  0000*         378
                         379
                         380
022A 95F4                381
022C 95F2                382
022E 97FD                383
0230 0F01  0000          384
0234 5E0E  0258'         385
0238 1CF1  0109          386
023C A1A1                387
023E 76D2  0002          388
0242 5F00  0000*         389
0246 5F00  041A'         390
024A 21F1                391
024C 2102  0004          392
0250 2102  0029          393
0254 5E08  029A'         394
0258 93FD                395
                         396 !PAGE

IC    R12,R4  !SIZE!
LDM   R1,@R15,#9 !RESTORE REGS 1-9!
LD    R7,R8  !SEG #!
SUB   R7,#NR OF KSEGS
MULT  RR6,#SIZEOF KST REC !OFFSET TO REC!
LD    R13,R7
ADD   R13,R9 !ADD KST TO OFFSET!
LDL   KST.CLASS(R13),RR10 !CLASS!
LD    KST.SIZE(R13),R12 !SIZE!
CPB   RL0,#SUCCEEDED
IF EQ THEN
   PUSH  @R15,R13
   CALL  TC_GET_PROC_CLASS
   !(RET:RR2:PROC_CLASS)!
   POP   R13,@R15
   LDL   RR4,KST.CLASS(R13)
   PUSH  @R15,R13
   PUSHL @R15,RR2
   PUSHL @R15,RR4
   CALL  CLASS_GE
   !(RR2:PROC_CLASS,RR4:SEG_CLASS,RET:
                        R1:CONDITION_CODE)!
   POPL  RR4,@R15
   POPL  RR2,@R15
   POP   R13,@R15
   CP    R1,#FALSE
   IF EQ THEN !NO ACCESS POSSIBLE--DEACT.!
       LDM   R1,@R15,#13
       LD    R1,R10   !DFR NO!
       LDA   R2,KST.MM_HANDLE(R13) !HPTR!
       CALL  MM_DEACTIVATE !RET:R0:S_CODE!
       CALL  CONFINEMENT_CHECK !RET:S_CODE!
       LD    R1,@R15 !SEG #!
       LD    R2,#NULL_ACCESS
       LD    R4,#PROC_CLASS_NOT_GE_SEG_CLASS
   ELSE
       PUSH  @R15,R13
```

```
!
025A 5F00  0000*     397                        CALL  CLASS_EQ !(RR2:PROC_CLASS,
                     398                     RR4:SEG CLASS,RET:R1:CONDITION_CODE)!
025E 97FD            399                        PCP   R13,@R15
0260 A110            400                        LD    R0,R1 !CONDITION_CODE!
0262 1CF1  010E      401                        LDM   R1,@R15,#9
0266 0B00  0001      402                        CP    R0,#TRUE
026A 5E0E  0282'     403                        IF EQ THEN
026F 0D05  0000      404                           CP    R5,#WRITE
0272 5E0E  027C'     405                           IF EQ THEN
0276 CA00            406                              LDB   RL2,#WRITE
0278 5E0E  027E'     407                           ELSE
027C CA01            408                              LDB   RL2,#READ
                     409                           FI
027E 5E0E  0284'     410                        ELSE
0282 CA01            411                           LDB   RL2,#READ
                     412                        FI
0284 4CD5  0009      413                        LDB   KST.IN_CORE(R13),#FALSE
0288 0000
028A 6EDE  000E      414                        LDB   KST.M_SEG_NO(R13),RL6
028F 6EDE  000F      415                        LDB   KST.ENTRY_NUMBER(R13),RL3
0292 6EDA  0008      416                        LDB   KST.ACCESS_MODE(R13),RL2
0296 2100  0002      417                        LD    R0,#SUCCEEDED !SUCCESS_CODE!
                     418                     FI
029A 5F0E  02A6'     419                  ELSE
029E 2101  FFFF      420                     LD    R1,#NULL_SEG
02A2 2102  0004      421                     LD    R2,#NULL_ACCESS
                     422                  FI
02A6 010F  0014      423                  ADD   R15,#20
02AA 5E0E  02BA'     424               ELSE
02AE 2100  001B      425                  LD    R0,#NO_SEG_AVAIL
02B2 2101  FFFF      426                  LD    R1,#NULL_SEG
02B6 2102  0004      427                  LD    R2,#NULL_ACCESS
                     428               FI
                     429            FI
                     430         FI
02BA 9E06            431         RET
02BC                 432      END MAKE_KNOWN
                     433 !PAGE
```

```
!
02FC                      TERMINATE                       PROCEDURE

                               !****************************************!
                               !  CHECKS VALIDITY OF TERMINATE REQUEST  !
                               !  AND CALLS MM_DEACTIVATE IF VALID      !
                               !****************************************!
                               !  REGISTER USE                          !
                               !  PARAMETERS                            !
                               !   R1:SEGMENT_NO(INPUT)                 !
                               !   R0:SUCCESS_CODE(RETURNED)            !
                               !  LOCAL USE                             !
                               !   R3:KST REC INDEX                     !
                               !   R6:CONSTANT STORAGE                  !
                               !   R13:^KST                             !
                               !****************************************!

                          ENTRY
02BC A113                      LD     R3,R1   !COPY OF SEG #!
02BE 0303  000A                SUB    R3,#NR_OF_KSEGS  !CONVERT SEG# TO KST INDEX!
02C2 1902  0010                MULT   RR2,#SIZEOF KST_REC
02C6 93F1                      PUSH   @R15,R1
02C8 93F3                      PUSH   @R15,R3
02CA 2101  0002                LD     R1,#KST_SEG_NO
02CE 5F00  0000*               CALL   ITC_GET_SEG_PTR  !(R1:KST_SEG NO)!
                                                       !(RETURNS:R0:KST_SEG PTR)!
02D2 A10D                      LD     R13,R0
02D4 97F3                      POP    R3,@R15
02D6 97F1                      POP    R1,@R15
02D8 813D                      ADD    R13,R3  !ADD OFFSET TO ^KST!
02DA 2106  FFFF                LD     R6,#NULL_SEG
02DE 4ADE  000E                CPB    RL6,KST.M_SEG_NO(R13)
02E2 5E0E  02EE'               IF     EQ     THEN
02E6 2100  001C                       LD     R0,#SEGMENT_NOT_KNOWN
02EA 5E08  0338'               ELSE
                      !PAGE
```

```
                !
02FE 2106  0001      469                LD    R6,#TRUE
0302 4ADE  0009      470                CPB   RL6,KST.IN_CORE(R13)
0306 5E0E  0302'     471                IF    EQ    THEN
030A 2106  001D      472                      LD    R0,#SEGMENT_IN_CORE
030E 5E08  0338'     473                ELSE
0312 0901  000A      474                      CP    R1,#NR_OF_KSEGS
0316 5F09  0312'     475                      IF    LT    THEN
031A 2100  001E      476                            LD    R0,#KERNEL_SEGMENT
031E 5E08  0338'     477                      ELSE
0322 93FD            478                            PUSH  @R15,R13
0324 5F00  0000*     479                            CALL  TC_GET_DBR_NO
                     480                                  !(RETURNS:RL1:DBR_NO)!
0328 97FD            481                            POP   R13,@R15
032A 76D2  0000      482                            LDA   R2,KST.MM_HANDLE(R13)
032F 93FD            483                            PUSH  @R15,R13
0330 5F00  0000*     484                            CALL  MM_DEACTIVATE !(R1:DIR_NO)!
                     485                                                !(R2:^MM_HANDLE)!
                     486                                             !(RET:R0:SUCCESS_CODE)!
0334 5F00  041A'     487                            CALL CONFINEMENT_CHECK
                     488                            !(R0:SUCCESS_CODE)!
0338 97FD            489                            POP   R13,@R15
033A 0A06  0202      490                            CPB   RL0,#SUCCEEDED
033E 5E0E  0338'     491                            IF    EQ    THEN !UPDATE KST!
0342 4CD5  000E      492                                  LDB   KST.M_SEG_NO(R13),
0346 FFFF                                                                #NULL_SEG
                     493                            FI
                     494                      FI
                     495                FI
                     496          FI
                     497          RET
0348 9E08            498     END TERMINATE
034A                 499 !PAGE
```

```
                                    !
033A                                501     SM_SWAP_IN                      PROCEDURE
                                    502
                                    503         !*****************************************!
                                    504         !  CHECKS VALIDITY OF SWAP IN REQUEST     !
                                    505         !  AND CALLS MM_SWAP_IN IF VALID          !
                                    506         !*****************************************!
                                    507         !  REGISTER USE                           !
                                    508         !  PARAMETERS                             !
                                    509         !   R1:SEGMENT_NO(INPUT)                  !
                                    510         !   R0:SUCCESS_CODE(RETURNED)             !
                                    511         !  LOCAL USE                              !
                                    512         !   R7:KST REC INDEX                      !
                                    513         !   R3:ACCESS_MODE                        !
                                    514         !   R6:CONSTANT STORAGE                   !
                                    515         !   R13:^KST                              !
                                    516         !*****************************************!
                                    517
                                    518     ENTRY
333A A117                           519         LD    R7,R1   !COPY OF SEG #!
333C 0307  000A                     520         SUI   R7,#NR_OF_KSEGS  !CONVERT SEG# TO KST_INDEX!
3340 1906  0010                     521         MULT  RR6,#SIZEOF KST_REC  !OFFSET TO KST_REC!
0344 93F1                           522         PUSH  @R15,R1  !SAVE SEGMENT#!
0346 93F7                           523         PUSH  @R15,R7
0348 2101  0002                     524         LD    R1,#KST_SEG_NO
034C 5F00  0000*                    525         CALL  ITC_GET_SEG_PTR  !(R1:KST_SEG_NO)!
0350 A10D                           526         LD    R13,R4   !^KST!
0352 97F7                           527         POP   R7,@R15
0354 97F1                           528         POP   R1,@R15  !RETRIEVE SEGMENT#!
0356 817D                           529         ADD   R13,R7  !ADD OFFSET TO KST BASE ADDR!
0358 2106  FFFF                     530         LD    R6,#NULL_SEG
035C 4ADE  000E                     531         CPB   RL6,KST.M_SEG_NO(R13)
0360 5F0E  036C'                    532         IF EQ THEN
0364 2100  001C                     533            LD    R0,#SEGMENT_NOT_KNOWN
0368 5E08  03AA'                    534         ELSE
                                    535 !PAGE
```

```
!
036C 2106  0001          LD     R6,#TRUE
0370 4ADE  0009          CPB    RL6,KST.IN_CORE(R13)
0374 5E0E  03E0'         IF EQ THEN
0378 2102  0002          LD     R0,#SUCCEEDED
037C 5E08  03AA'         ELSE
0380 93FD                   PUSH   @R15,R13  !SAVE KST REC ADDR!
0382 5F00  0000*            CALL   TC_GET_DBR_NO  !R1:(RET)DBR_NO!
0386 97FD                   POP    R13,@R15
0388 76D2  0000             LDA    R2,KST.MM_HANDLE(R13)
038C 60DB  0028             LDB    RL3,KST.ACCESS_MODE(R13)
0390 93FD                   PUSH   @R15,R13  !SAVE SEG KST REC ADDR!
0392 5F00  0000*            CALL   MM_SWAP_IN  !(R1:DBR_NO)  !
                                               !(R2:^MM_HANDLE)!
                                               !(R3:ACCESS_MODE)!
                                               !(R0:(RET)SUCCESS_CODE)!
0396 5F00  041A'            CALL CONFINEMENT_CHECK !(R0:SUCCESS_CODE)!
039A 97FD                   POP    R13,@R15
039C 0A08  0202             CPB    RL0,#SUCCEEDED
03A0 5E0E  03AA'            IF     EQ    THEN
03A4 4CD5  0009                    LDB   KST.IN_CORE(R13),#TRUE
03A8 0101
                            FI
                         FI
                      FI
03AA 9E08             RET
03AC              END SM_SWAP_IN
     !PAGE
```

```
                                !
03AC                    562     SM_SWAP_OUT                     PROCEDURE
                        563
                        564         !*****************************************!
                        565         !  CHECKS VALIDITY OF SWAP OUT REQUEST    !
                        566         !  AND CALLS MM_SWAP_OUT IF VALID         !
                        567         !*****************************************!
                        568         !  REGISTER USE                           !
                        569         !  PARAMETERS                             !
                        570         !   R1:SEGMENT_NO                         !
                        571         !   R0:SUCCESS_CODE(RETURNED)             !
                        572         !  LOCAL USES                             !
                        573         !   R7:KST REC INDEX                      !
                        574         !   R6:CONSTANT STORAGE                   !
                        575         !   R13:^KST                              !
                        576         !*****************************************!
                        577
                        578     ENTRY
03AC A117               579         LD      R7,R1   !COPY OF SEG #!
03AE 0337  00DA         580         SUB     R7,#NR_OF_KSEGS  !CONVERT SEG# TO KST INDEX!
03B2 1006  0010         581         MULT    RR6,#SIZEOF KST_REC  !OFFSET TO KST_REC!
03B6 93F1               582         PUSH    @R15,R1  !SAVE SEGMENT#!
03B8 93F7               583         PUSH    @R15,R7
03BA 2101  0002         584         LD      R1,#KST_SEG_NO
03BE 5F00  0000*        585         CALL    ITC_GET_SEG_PTR  !(R1:KST_SEG_NO)!
03C2 A10D               586         LD      R13,R0  !^KST!
03C4 97F7               587         POP     R7,@R15
03C6 97F1               588         POP     R1,@R15  !RETRIEVE SEGMENT#!
03C8 817D               589         ADD     R13,R7  !ADD OFFSET TO KST BASE ADDR!
03CA 2106  FFFF         590         LD      R6,#NULL_SEG
03CE 4ADE  000E         591         CPR     RL6,KST.M_SEG_NO(R13)
03D2 5E2E  03DE'        592         IF EQ THEN
03D6 2106  001C         593            LD      R6,#SEGMENT_NOT_KNOWN
03DA 5E2E  0416'        594         ELSE
03DE 2106  0000         595            LD      R6,#FALSE
                        596 !PAGE
```

```
                !
03F2 4ADE  0009      597             CPB   RL6,KST.IN_CORE(R13)
03E6 5E0E  03F2'     598             IF EQ THEN
03FA 2100  0002      599                LD    R0,#SUCCEEDED
03EE 5E06  0418'     600             ELSE
03F2 93FD            601                PUSH  @R15,R13  !SAVE KST REC ADDR!
03F4 5F00  0000*     602                CALL  TC_GET_DBR_NO  !R1:(RFT)DBR_NO!
03F8 97FD            603                POP   R13,@R15
03FA 76D2  0000      604                LDA   R2,KST.MM_HANDLE(R13)
03FE 93FL            605                PUSH  @R15,R13  !SAVE SEG KST REC ADDR!
0400 5F00  0000*     606                CALL  MM_SWAP_OUT !(R1:DBR_NO) !
                     607                                  !(R2:^MM_HANDLE)!
                     608                                  !(R0:(RFT)SUCCESS_CODE)!
0404 5F00  041A'     609                CALL CONFINEMENT_CHECK !(R0:SUCCESS_CODE)!
0408 97FD            610                POP   R13,@R15
040A 0A06  0202      611                CPB   RL0,#SUCCEEDED
040E 5E0E  0418'     612                IF    EQ    THEN
0412 4CD5  0009      613                      LDB   KST.IN_CORE(R13),#FALSE
0416 0000
                     614                FI
                     615             FI
                     616          FI
0418 9E08            617          RET
041A                 618       END SM_SWAP_OUT
                     619
                     620 !PAGE
```

```
                        !
041A                    621     CONFINEMENT_CHECK                       PROCEDURE
                        622
                        623         !***************************************************!
                        624         !                                                   !
                        625         !     SERVICE RCUTINE TO VERIFY CONFINEMENT IS      !
                        626         !     NOT VIOLATED WHEN MEM MGR SUCCESS CODE IS     !
                        627         !     RETURNED TO SUPERVISOR.                       !
                        628         !***************************************************!
                        629         !     REGISTER USE:                                 !
                        630         !     PARAMETERS                                    !
                        631         !      R0:SUCCESS CODE                              !
                        632         !***************************************************!
                        633
                        634     ENTRY
                        635         IF R0
041A 0F00  000A         636             CASE #LEAF_SEG_EXISTS THEN CALL MONITOR
041E 5E0E  042A'
0422 5F00  059A
0426 5E0E  04A6'        637             CASE #NO_LEAF_EXISTS THEN CALL MONITOR
042A 0B00  000B
042E 5E0E  043A'
0432 5F00  059A
0436 5E0E  04A6'        638             CASE #ALIAS_DOES_NOT_EXIST THEN CALL MONITOR
043A 0B00  0017
043E 5F0F  044A'
0442 5F00  059A
0446 5E0E  04A6'        639             CASE #NO_CHILD_TO_DELETE THEN CALL MONITOR
044A 0F00  0014
044E 5E0E  045A'
0452 5F00  059A
0456 5F0E  04A6'        640             CASE #; AST_FULL THEN CALL MONITOR
045A 0B00  000C
045E 5E0E  046A'
0462 5F00  059A
                        641 !PAGE
```

```
                !
0466 5E08 04A6'     642             CASE #L_AST_FULL THEN CALL MONITOR
046A 0B00 0001
046E 5E0E 047A'
0472 5F00 059A
0476 5E08 04A6'     643             CASE #LOCAL_MEMORY_FULL THEN CALL MONITOR
047A 0B00 0010
047E 5E0E 048A'
0482 5F00 059A
0486 5E08 04A6'     644             CASE #GLOBAL_MEMORY_FULL THEN CALL MONITOR
048A 0B00 0011
048E 5E0E 049A'
0492 5F00 059A
0496 5E08 04A6'     645             CASE #SEC_STOR_FULL THEN CALL MONITOR
049A 0B00 0015
049E 5E0E 04A6'
04A2 5F00 059A
                    646         FI
04A6 9E08           647         RET
04A8                648     END CONFINEMENT_CHECK
                    649
                    650     END SEG_MGR
                    651
                    652 !PAGE
```

APPENDIX C - DISTRIBUTED MEMORY MANAGER PL/SYS LISTINGS

```
DIST_MMGR MODULE


CONSTANT
        CREATE_ENTRY_CODE           := 50
        DELETE_ENTRY_CODE           := 51
        ACTIVATE_SEG_CODE           := 52
        DEACTIVATE_SEG_CODE         := 53
        SWAP_IN_SEG_CODE            := 54
        SWAP_OUT_SEG_CODE           := 55
        NO_OF_PROCESSORS            := 1
        MAX_NO_KST_ENTRIES          := ??
        MAX_SEG_SIZE                := ??
        MAX_DBR_NO                  := 4
        NR_OF_KSEGS                 := ??
        KST_SEG_NO                  := ??

TYPE
        H_ARRAY          ARRAY [3   WORD]

        COM_MSG          ARRAY [16  BYTE]

        CREATE_MSG       RECORD [CREATE_CODE    WORD
                                 CE_MM_HANDLE   H_ARRAY
                                 CE_ENTRY_NO    SHORT_INTEGER
                                 CE_FILLER      BYTE
                                 CE_SIZE        WORD
                                 CE_CLASS       LONG]

        DELETE_MSG       RECORD [DELETE_CODE    WORD
                                 DE_MM_HANDLE   H_ARRAY
                                 DE_ENTRY_NO    SHORT_INTEGER
                                 DE_FILLER      ARRAY[7 BYTE]]

        ACTIVATE_MSG     RECORD [ACTIVATE_CODE WORD
                                 A_DBR_NO       SHORT_INTEGER
                                 A_FILLER1      BYTE
                                 A_MM_HANDLE    H_ARRAY
                                 A_ENTRY_NO     SHORT_INTEGER
                                 A_SEGMENT_NO   SHORT_INTEGER
                                 A_FILLER2      LONG]

        DEACTIVATE_MSG   RECORD [DEACTIVATE_CODE WORD
                                 D_DBR_NO       SHORT_INTEGER
                                 D_FILLER1      BYTE
                                 D_MM_HANDLE    H_ARRAY
                                 D_FILLER2      ARRAY[3 WORD]]
```

```
SWAP_IN_MSG       RECORD [SWAP_IN_CODE  WORD
                          SI_MM_HANDLE  H_ARRAY
                          SI_DBR_NO     SHORT_INTEGER
                          SI_ACCESS_ALTH BYTE
                          SI_FILLER     ARRAY[3 WORD]]

SWAP_OUT_MSG      RECORD [SWAP_OUT_CODE WORD
                          SO_DBR_NO     SHORT_INTEGER
                          SO_FILLER1    BYTE
                          SO_MM_HANDLE  H_ARRAY
                          SO_FILLER2    ARRAY[3 WORD]]

R_SUC_CODE        RECORD [SUC_CODE      BYTE
                          SC_FILLER     ARRAY[15 BYTE]
                         ]

R_ACTIVATE_ARG    RECORD [R_SUC_CODE    BYTE
                          R_FILLER      BYTE
                          R_MM_HANDLE   H_ARRAY
                          R_CLASS       LONG
                          R_SIZE        WORD]

CE_PTR            ^CREATE_MSG

DE_PTR            ^DELETE_MSG

A_PTR             ^ACTIVATE_MSG

D_PTR             ^DEACTIVATE_MSG

SI_PTR            ^SWAP_IN_MSG

SO_PTR            ^SWAP_OUT_MSG

SC_PTR            ^R_SUC_CODE

ARG_PTR           ^R_ACTIVATE_ARG

KST_REC           RECORD [ MM_HANDLE      H_ARRAY
                           SIZE           WORD
                           ACCESS_MODE    BYTE
                           IN_CORE        BYTE
                           CLASS          LONG
                           M_SEG_NO       SHORT_INTEGER
                           ENTRY_NUMBER   SHORT_INTEGER ]

KST               ARRAY  [ MAX_NO_KST_ENTRIES KST_REC ]
```

```
        KSTPTR          ^KST

        ADDRESS         WORD

        SEG_DESC_REG    RECORD [BASE_ADDR   ADDRESS
                                LIMIT       BYTE
                                ATTRIBUTE   BYTE]

        MMU             RECORD [SDR   ARRAY [NO_SEG_DESC_REG
                                             SEG_DESC_REG]
                                BLKS_USED   WORD
                                MAX_BLKS    WORD]

        MM_VP_ID        WORD

        SEG_ARRAY       ARRAY [MAX_SEG_SIZE     BYTE]

        SEGPTR          ^SEG_ARRAY


INTERNAL

        MM_CPU_TABLE    ARRAY [NO_OF_PROCESSORS MM_VP_ID]

EXTERNAL

        MMU_IMAGE       ARRAY [MAX_DBR_NO   MMU]

        G_AST_LOCK      BYTE

        K_LOCK          PROCEDURE

        K_UNLOCK        PROCEDURE

        ITC_GET_CPU_NO  PROCEDURE

        SIGNAL          PROCEDURE

        WAIT            PROCEDURE
```

```
!*****************************************************************
*                                                                 *
*     MM_CREATE_ENTRY PROCEDURE. INVOKED BY SEGMENT               *
*     MANAGER'S CREATE SEGMENT PROCEDURE. PERFORMS TYPE           *
*     CONVERSION OF POINTERS, LOADS MESSAGE ARRAY FOR             *
*     IPC, AND PERFORMS IPC WITH MEMORY MANAGER PROCESS.          *
*     RETURNS SUCCESS_CODE.                                       *
*                                                                 *
*****************************************************************!


MM_CREATE_ENTRY  PROCEDURE  ( HPTR            ^H_ARRAY
                              ENTRY_NO        SHORT_INTEGER
                              SIZE            WORD
                              CLASS           LONG )
                 RETURNS    ( SUCCESS_CODE   BYTE )

! **** NOTE:    REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL    CE_MSGPTR     CE_PTR
         COM_MSGBUF    COM_MSG
         COM_MSGPTR    ^COM_MSG
         SUC_CODE_PTR  SC_PTR

ENTRY
    COM_MSGPTR     := #COM_MSGBUF
    ! TYPE CONVERT TO OVERLAY ARGUMENT LIST ONTO MSG LIST !
    CE_MSGPTR      := CE_PTR COM_MSGPTR
    ! LOAD ARG LIST ONTO MSG ARRAY !
    CE_MSGPTR^.CREATE_CODE := CREATE_ENTRY_CODE
    CE_MSGPTR^.CE_MM_HANDLE[0] := HPTR^[0]
    CE_MSGPTR^.CE_MM_HANDLE[1] := HPTR^[1]
    CE_MSGPTR^.CE_MM_HANDLE[2] := HPTR^[2]
    CE_MSGPTR^.CE_ENTRY_NO := ENTRY_NO
    CE_MSGPTR^.CE_CLASS := CLASS
    CE_MSGPTR^.CE_SIZE  := SIZE
    PERFORM_IPC (COM_MSGPTR)
    ! TYPE CONVERT TO OVERLAY MSG ARRAY ONTO RET ARG LIST !
    SUC_CODE_PTR := SC_PTR COM_MSGPTR
    SUCCESS_CODE := SUC_CODE_PTR^.SUC_CODE
    RETURN
END MM_CREATE_ENTRY
```

```
!*****************************************************************************
*                                                                           *
*     MM_DELETE_ENTRY PROCEDURE. INVOKED BY SEGMENT                         *
*     MANAGER'S DELETE_SEGMENT PROCEDURE. PERFORMS TYPE                     *
*     CONVERSION OF POINTERS, LOADS MESSAGE ARRAY FOR                       *
*     IPC, AND PERFORMS IPC WITH MEMORY MANAGER PROCESS.                    *
*     RETURNS SUCCESS_CODE.                                                 *
*                                                                           *
*****************************************************************************!


MM_DELETE_ENTRY  PROCEDURE  ( HPTR              ^H_ARRAY
                              ENTRY_NO          SECRT_INTEGER)
                 RETURNS    ( SUCCESS_CODE     BYTE )

! **** NOTE:    REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL    DE_MSGPTR    DE_PTR
         COM_MSGBUF   COM_MSG
         COM_MSGPTR   ^COM_MSG
         SUC_CODE_PTR SC_PTR

ENTRY
    COM_MSGPTR     := #COM_MSGBUF
    ! TYPE CONVERSION TO OVERLAY ARG LIST ONTO MSG ARRAY !
    DE_MSGPTR := DE_PTR COM_MSGPTR
    ! LOAD ARG LIST ONTO MSG ARRAY !
    DE_MSGPTR^.DELETE_CODE := DELETE_ENTRY_CODE
    DE_MSGPTR^.DE_MM_HANDLE[0]  := HPTR^[0]
    DE_MSGPTR^.DE_MM_HANDLE[1]  := HPTR^[1]
    DE_MSGPTR^.DE_MM_HANDLE[2]  := HPTR^[2]
    DE_MSGPTR^.DE_ENTRY_NO := ENTRY_NO
    PERFORM_IPC (COM_MSGPTR)
    ! TYPE CONVERT TO OVERLAY MSG ARRAY ONTO ARG LIST !
    SUC_CODE_PTR := SC_PTR COM_MSGPTR
    SUCCESS_CODE := SUC_CODE_PTR^.SUC_CODE
    RETURN
END MM_DELETE_ENTRY
```

```
!*****************************************************************
*                                                                 *
*    MM_ACTIVATE PROCEDURE. INVOKED BY SEGMENT MANA-              *
*    GER'S MAKE_KNOWN PROCEDURE. PERFORMS TYPE CONVERSION         *
*    OF POINTERS, LOADS MESSAGE ARRAY FOR IPC, AND UP-            *
*    DATES MM_HANDLE ENTRY IN KST AFTER PERFORMING THE            *
*    IPC. RETURNS SUCCESS_CODE, CLASS, AND SIZE.                  *
*                                                                 *
*****************************************************************!

MM_ACTIVATE  PROCEDURE  ( DBR_NO          SHORT_INTEGER
                          HPTR            ^H_ARRAY
                          ENTRY_NO        SHORT_INTEGER
                          SEGMENT_NO      SHORT_INTEGER )
                RETURNS   ( SUCCESS_CODE  BYTE
                          CLASS           LONG
                          SIZE            WORD )
! **** NOTE:    REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL    A_MSGPTR    A_PTR
         COM_MSGBUF  COM_MSG
         COM_MSGPTR  ^COM_MSG
         RET_ARGPTR  ARGPTR
         KPTR        KSTPTR
         INDEX       SHORT_INTEGER
ENTRY
    COM_MSGPTR := #COM_MSGBUF
    ! TYPE CONVERT TO OVERLAY ARG LIST ONTO MSG ARRAY !
    A_MSGPTR := A_PTR COM_MSGPTR
    ! LOAD ARG LIST ONTO MSG ARRAY !
    A_MSGPTR^.ACTIVATE_CODE := ACTIVATE_SEG_CODE
    A_MSGPTR^.A_DBR_NO := DBR_NO
    A_MSGPTR^.A_MM_HANDLE[0] := HPTR^[0]
    A_MSGPTR^.A_MM_HANDLE[1] := HPTR^[1]
    A_MSGPTR^.A_MM_HANDLE[2] := HPTR^[2]
    A_MSGPTR^.A_ENTRY_NO := ENTRY_NO
    A_MSGPTR^.A_SEGMENT_NO := SEGMENT_NO
    PERFORM_IPC (COM_MSGPTR)
    ! TYPE CONVERT TO OVERLAY MSG ARRAY ONTO RET ARG LIST !
    RET_ARGPTR := ARG_PTR COM_MSGPTR
    SUCCESS_CODE := RET_ARGPTR^.R_SUC_CODE
    CLASS := RET_ARGPTR^.R_CLASS
    SIZE := RET_ARGPTR^.R_SIZE
    INDEX := SEGMENT_NO - NR_OF_KSEGS
    ! RETRIEVE HANDLE AND UPDATE KST !
    KPTR := KSTPTR MM_GET_KSEG_PTR ( SEG_NO )
    HPTR := #KPTR^[INDEX].MM_HANDLE
    HPTR^[0] := RET_ARGPTR^.R_MM_HANDLE[0]
    HPTR^[1] := RET_ARGPTR^.R_MM_HANDLE[1]
    HPTR^[2] := RET_ARGPTR^.R_MM_HANDLE[2]
    RETURN
END MM_ACTIVATE
```

```
!*****************************************************************
*                                                                 *
*    MM_DEACTIVATE PROCEDURE. INVOKED BY SEG MGR'S                *
*    DEACTIVATE PROCEDURE. PERFORMS TYPE CONVERSION               *
*    OF POINTERS, LOADS MESSAGE ARRAY FOR IPC, AND PER-           *
*    FORMS IPC. RETURNS SUCCESS_CODE.                             *
*                                                                 *
*****************************************************************!


MM_DEACTIVATE   PROCEDURE  ( DBR_NO       SHORT_INTEGER
                             HPTR        ^H_ARRAY )
                RETURNS    ( SUCCESS_CODE  BYTE )

! **** NOTE:    REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL   D_MSGPTR   D_PTR
        COM_MSGBUF COM_MSG
        COM_MSGPTR ^COM_MSG
        SUC_CODE_PTR SC_PTR

ENTRY
    COM_MSGPTR := #COM_MSGBUF
    ! TYPE CONVERT TO OVERLAY ARG LIST ONTO MSG ARRAY !
    D_MSGPTR := D_PTR COM_MSGPTR
    ! LOAD ARG LIST ONTO MSG ARRAY !
    D_MSGPTR^.DEACTIVATE_CODE := DEACTIVATE_SEG_CODE
    D_MSGPTR^.D_DBR_NO := DBR_NO
    D_MSGPTR^.D_MM_HANDLE[0] := HPTR^[0]
    D_MSGPTR^.D_MM_HANDLE[1] := HPTR^[1]
    D_MSGPTR^.D_MM_HANDLE[2] := HPTR^[2]
    PERFORM_IPC (COM_MSGPTR)
    ! TYPE CONVERT TO OVERLAY MSG ARRAY ONTO RET ARG LIST !
    SUC_CODE_PTR := SC_PTR COM_MSGPTR
    SUCCESS_CODE := SUC_CODE_PTR^.SUC_CODE
    RETURN
END MM_DEACTIVATE
```

```
!*****************************************************************
*                                                                 *
*    MM_SWAP_IN PROCEDURE. INVOKED BY SEGMENT MANAGER'S           *
*    SM_SWAP_IN PROCEDURE. PERFORMS TYPE CONVERSION OF            *
*    POINTERS, LOADS MESSAGE ARRAY FOR IPC, AND PERFORMS          *
*    IPC. RETURNS SUCCESS_CODE.                                   *
*                                                                 *
*****************************************************************!


MM_SWAP_IN   PROCEDURE  ( DBR_NO          SHORT_INTEGER
                          HPTR            ^H_ARRAY
                          ACCESS_MODE     BYTE )
             RETURNS    ( SUCCESS_CODE   BYTE )

! **** NOTE:    REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !
LOCAL   SI_MSGPTR     SI_PTR
        COM_MSGBUF    COM_MSG
        COM_MSGPTR    ^COM_MSG
        SUC_CODE_PTR SC_PTR

ENTRY
    COM_MSGPTR := #COM_MSGBUF
    ! TYPE CONVERT TO OVERLAY ARG LIST ONTO MSG ARRAY !
    SI_MSGPTR := SI_PTR COM_MSGPTR
    ! LOAD ARG LIST ONTO MSG ARRAY !
    SI_MSGPTR^.SWAP_IN_CODE := SWAP_IN_SEG_CODE
    SI_MSGPTR^.SI_MM_HANDLE[0] := HPTR^[0]
    SI_MSGPTR^.SI_MM_HANDLE[1] := HPTR^[1]
    SI_MSGPTR^.SI_MM_HANDLE[2] := HPTR^[2]
    SI_MSGPTR^.SI_DBR_NO := DBR_NO
    SI_MSGPTR^.SI_ACCESS_AUTH := ACCESS_MODE
    PERFORM_IPC (COM_MSGPTR)
    ! TYPE CONVERT TO OVERLAY MSG ARRAY ONTO RET ARG LIST !
    SUC_CODE_PTR := SC_PTR COM_MSGPTR
    SUCCESS_CODE := SUC_CODE_PTR^.SUC_CODE
    RETURN
END MM_SWAP_IN
```

```
!*****************************************************************
*                                                               *
*    MM_SWAP_OUT PROCEDURE. INVOKED BY SEGMENT MANAGER'S        *
*    SM_SWAP_OUT PROCEDURE. PERFORMS TYPE CONVERSION OF         *
*    POINTERS, LOADS MESSAGE ARRAY FOR IPC, AND PERFORMS        *
*    IPC. RETURNS SUCCESS_CODE.                                 *
*                                                               *
*****************************************************************!


MM_SWAP_OUT   PROCEDURE  ( HPTR          ^H_ARRAY
                           ACCESS_MODE   BYTE )
              RETURNS    ( SUCCESS_CODE  BYTE )

! **** NOTE:    REENTRANT  PROCEDURE    **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL   SO_MSGPTR     SO_PTR
        COM_MSGBUF    COM_MSG
        COM_MSGPTR    ^COM_MSG
        SUC_CODE_PTR  SC_PTR

ENTRY
    COM_MSGPTR := #COM_MSGBUF
    ! TYPE CONVERT TO OVERLAY ARG LIST ONTO MSG ARRAY !
    SO_MSGPTR := SO_PTR COM_MSGPTR
    ! LOAD ARG LIST ONTO MSG ARRAY !
    SO_MSGPTR^.SWAP_OUT_CODE := SWAP_OUT_SEG_CODE
    SO_MSGPTR^.SO_MM_HANDLE[0] := HPTR^[0]
    SO_MSGPTR^.SO_MM_HANDLE[1] := HPTR^[1]
    SO_MSGPTR^.SO_MM_HANDLE[2] := HPTR^[2]
    SO_MSGPTR^.SO_DBR_NO := DBR_NO
    PERFORM_IPC (COM_MSGPTR)
    ! TYPE CONVERT TO OVERLAY MSG ARRAY ONTO RET ARG LIST !
    SUC_CODE_PTR := SC_PTR COM_MSGPTR
    SUCCESS_CODE := SUC_CODE_PTR^.SUC_CODE
    RETURN
END MM_SWAP_OUT
```

```
!*****************************************************************
*                                                                 *
*     MM_GET_DBR_VALUE. SERVICE ROUTINE THAT RETRIEVES            *
*     THE DBR "VALUE" (IE ADDRESS) BASED UPON A DBR_NO.           *
*                                                                 *
*****************************************************************!

MM_GET_DBR_VALUE     PROCEDURE  (DBR_NO   SHORT_INTEGER)
                     RETURNS    (DBR_VALUE ADDRESS)

! **** NOTE:     REENTRANT  PROCEDURE     **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

ENTRY
    DBR_VALUE := #MMU_IMAGE [DBR_NO]
    RETURN
END MM_GET_DBR_VALUE



!*****************************************************************
*                                                                 *
*     PERFORM_IPC PROCEDURE. INVOKED BY DISTRIBUTED               *
*     MEMORY MANAGER PROCEDURES. DETERMINES CURRENT               *
*     MEMORY MANAGER'S VP_ID, LOCKS G_AST, PERFORMS               *
*     IPC VIA SIGNAL AND WAIT PRIMITIVES, AND UNLOCKS             *
*     THE G_AST.                                                  *
*                                                                 *
*****************************************************************!


PERFORM_IPC     PROCEDURE   (COM_MSGPTR     ^COM_MSG)

! **** NOTE:     REENTRANT  PROCEDURE     **** !
! SAVE LOCAL VARIABLES ON STACK TO ENSURE REENTRANT !

LOCAL     MMGR_VP_ID

ENTRY
    ! DETERMINE MMGR_VP_ID !
    CPU_NO := ITC_GET_CPU_NO
    MMGR_VP_ID := MM_CPU_TABLE [CPU_NO]
    K_LOCK (#G_AST_LOCK)
    ! IPC WITH MEMORY MANAGER PROCESS !
    SIGNAL ( COM_MSGPTR, MMGR_VP_ID )
    WAIT ( COM_MSGPTR )
    K_UNLOCK (#G_AST_LOCK )
    RETURN
END PERFORM_IPC

END DIST_MMGR
```

```
 2 !    APPENDIX D - DISTRIBUTED MEMORY MANAGER PLZ/ASM LISTINGS
 3 !
 4      DIST_MM MODULE
 5
 6      CONSTANT
 7
 8      CREATE_ENTRY_CODE           := 50
 9      DELETE_ENTRY_CODE           := 51
10      ACTIVATE_SEG_CODE           := 52
11      DEACTIVATE_SEG_CODE         := 53
12      SWAP_IN_SEG_CODE            := 54
13      SWAP_OUT_SEG_CODE           := 55
14      NO_OF_PROCESSORS            := 1
15      MAX_NO_KST_ENTRIES          := 54
16      MAX_SEG_SIZE                := 128
17      MAX_DBR_NO                  := 4
18      KST_SEG_NO                  := 2
19      NR_OF_KSEGS                 := 10
20
21      TYPE
22
23      H_ARRAY              ARRAY [ 3   WORD ]
24
25      COM_MSG            ARRAY [16  BYTE]
26
27      KST_REC            RECORD [ MM_HANDLE      H_ARRAY
28                             SIZE              WORD
29                             ACCESS_MODE       BYTE
30                             IN_CORE           BYTE
31                             CLASS             LONG
32                             M_SEG_NO          SHORT_INTEGER
33                             ENTRY_NUMBER      SHORT_INTEGER ]
34
35      ADDRESS            WORD
36 !PAGE
```

```
!
                    37      SEG_DESC_REG      RECORD [BASE_ADDR  ADDRESS
                    38                               LIMIT      BYTE
                    39                               ATTRIBUTE  BYTE]
                    40
                    41      MMU               RECORD [SDR  ARRAY [64
                    42                                    SEG_DESC_REG]]
                    43                          !NOTE: NEXT TWO COMPONENTS
                    44                          LEFT OUT FOR CONVENIENCE SINCE
                    45                          ARE NOT USED FOR SEGMENT MGR
                    46                          DEMO!
                    47                                       !BLKS_USED  WORD
                    48                                       MAX_BLKS    WORD]!
                    49
                    50      MM_VP_ID          WORD
                    51
                    52      SEG_ARRAY       ARRAY [MAX_SEG_SIZE    BYTE]
                    53
                    54      INTERNAL
142                 55
                    56      $SECTION D_MM_DATA
0000 0000           57      MM_CPU_TABLE ARRAY [NO_OF_PROCESSORS MM_VP_ID] :=[0]
                    58
                    59      $SECTION MSG_FRAME_DCL
                    60      !NOTE: THESE RECORDS ARE "OVERLAYS" OR "FRAMES" USED
                    61       TO DEFINE MESSAGE FORMATS. NO MEMORY IS ALLOCATED FOR
                    62       THEM!
                    63      $ABS 0
0000                64      CREATE_MSG        RECORD [CREATE_CODE   WORD
                    65                               CE_MM_HANDLE  E_ARRAY
                    66                               CE_ENTRY_NO   SHORT_INTEGER
                    67                               CE_FILLER     BYTE
                    68                               CE_SIZE       WORD
                    69                               CE_CLASS      LONG]
                    70
                    71  !PAGE
```

```
!
                    72      $ABS 0
0000                73      DELETE_MSG          RECORD [DELETE_CODE    WORD
                    74                                  DE_MM_HANDLE   H_ARRAY
                    75                                  DE_ENTRY_NO    SHORT_INTEGER
                    76                                  DE_FILLER      ARRAY[7 BYTE]]
                    77
                    78      $ABS 0
0000                79      ACTIVATE_MSG    RECORD [ACTIVATE_CODE WORD
                    80                              A_DBR_NO       SHORT_INTEGER
                    81                              A_FILLER1      BYTE
                    82                              A_MM_HANDLE    H_ARRAY
                    83                              A_ENTRY_NO     SHORT_INTEGER
                    84                              A_SEGMENT_NO   SHORT_INTEGER
                    85                              A_FILLER2      LONG]
                    86
                    87      $ABS 0
0000                88      DEACTIVATE_MSG     RECORD [DEACTIVATE_CODE WORD
                    89                                 D_DBR_NO       SHORT_INTEGER
                    90                                 D_FILLER1      BYTE
                    91                                 D_MM_HANDLE    H_ARRAY
                    92                                 D_FILLER2      ARRAY[3 WORD]]
                    93
                    94      $ABS 0
0000                95      SWAP_IN_MSG         RECORD [SWAP_IN_CODE   WORD
                    96                                  SI_MM_HANDLE   H_ARRAY
                    97                                  SI_DBR_NO      SHORT_INTEGER
                    98                                  SI_ACCESS_AUTH BYTE
                    99                                  SI_FILLER      ARRAY[3 WORD]]
                   100      $ABS 0
0000               101      SWAP_OUT_MSG        RECORD [SWAP_OUT_CODE WORD
                   102                                 SO_DBR_NO      SHORT_INTEGER
                   103                                 SO_FILLER1     BYTE
                   104                                 SO_MM_HANDLE   H_ARRAY
                   105                                 SO_FILLER2     ARRAY[3 WORD]]
                   106  !PAGE
```

```
!
                    107     $ABS 0
0000                108     RET_SUC_CODE        RECORD [SUC_CODE       BYTE
                    109                                 SC_FILLER      ARRAY[15 BYTE]
                    110                                ]
                    111
                    112     $ABS 0
0000                113     R_ACTIVATE_ARG    RECORD [R_SUC_CODE     BYTE
                    114                               R_FILLER       BYTE
                    115                               R_MM_HANDLE    H_ARRAY
                    116                               R_CLASS        LONG
                    117                               R_SIZE         WORD
                    118                                      R_FILLER1      WORD]
                    119
                    120     $ABS 0
0000                121     KST                 ARRAY   [ MAX_NO_KST_ENTRIES KST_REC ]
                    122
                    123
                    124     EXTERNAL
                    125
                    126             MMU_IMAGE           ARRAY [MAX_DBR_NO  MMU]
                    127
                    128             G_AST_LOCK          WORD
                    129
                    130             K_LOCK              PROCEDURE
                    131
                    132             K_UNLOCK            PROCEDURE
                    133
                    134             ITC_GET_CPU_NO      PROCEDURE
                    135
                    136             SIGNAL              PROCEDURE
                    137
                    138             WAIT                PROCEDURE
                    139
                    140             ITC_GET_SEG_PTR     PROCEDURE
                    141 !PAGE
```

```
!
                        142     GLOBAL
                        143     $SECTION D_MM_PROC
0000                    144     MM_CREATE_ENTRY                 PROCEDURE
                        145         !*********************************!
                        146         ! INTERFACE BETWEEN SEG MGR      !
                        147         ! (CREATE_SEG PROCEDURE) AND     !
                        148         ! MMGR PROCESS (CREATE_ENTRY     !
                        149         ! PROCEDURE). ARRANGES AND       !
                        150         ! PERFORMS IPC.                  !
                        151         !*********************************!
                        152         ! REGISTER USE:                  !
                        153         ! PARAMETERS                     !
                        154         !  R0:SUCCESS CODE (RET)         !
                        155         !  R1:HPTR (INPUT)               !
                        156         !  R2:ENTRY_NO (INPUT)           !
                        157         !  R3:SIZE (INPUT)               !
                        158         !  RR4:CLASS (INPUT)             !
                        159         ! LOCAL USE                      !
                        160         !  R6:MM_HANDLE ARRAY ENTRY      !
                        161         !  R8:^COM_MSGBUF                !
                        162         !  R13:^COM_MSGBUF               !
                        163         !*********************************!
                        164     ENTRY
0000 030F  0010         165         SUB   R15,#SIZEOF COM_MSG  !USE STACK FOR MESSAGE!
0004 A1FD               166         LD    R13,R15   ! ^COM_MSGBUF !
                        167
                        168         !FILL COM_MSGBUF (LOAD MESSAGE). CREATE_MSG FRAME
                        169          IS BASED AT ADDRESS ZERO. IT IS OVERLAID ONTO
                        170          COM_MSGBUF FRAME BY INDEXING EACH ENTRY (I.E. ADD-
                        171          ING TO EACH ENTRY) THE BASE ADDRESS OF COM_MSGBUF!
                        172
0006 4DD5  0000         173         LD    CREATE_MSG.CREATE_CODE(R13),#CREATE_ENTRY_CODE
0008 0032
000C 3116  0000         174         LD    R6,R1(#0)  !INDEX TO MM_HANDLE ENTRY!
0010 6FD6  0002         175         LD    CREATE_MSG.CE_MM_HANDLE[0](R13),R6
0014 3116  0002         176         LD    R6,R1(#2)
                        177 !PAGE
```

```
!
0018 6FD6  0004      178          LD    CREATE_MSG.CE_MM_HANDLE[1](R13),R6
001C 3116  0004      179          LD    R6,R1(#4)
0020 6FD6  0006      180          LD    CREATE_MSG.CE_MM_HANDLE[2](R13),R6
0024 6FD2  0008      181          LD    CREATE_MSG.CE_ENTRY_NO(R13),R2
0028 5DD4  000C      182          LDL   CREATE_MSG.CE_CLASS(R13),RR4
002C 6FD3  000A      183          LD    CREATE_MSG.CE_SIZE(R13),R3
0030 A1D8            184          LD    R8,R13
0032 5F00  01A8'     185          CALL  PERFORM_IPC  !R8: ^COM_MSGBUF!
                     186          !RETRIEVE SUCCESS_CODE FROM RETURNED MESSAGE!
0036 60D8  0000      187          LDB   RL0,RFT_SUC_CODE.SUC_CODE(R13)
003A 010F  0010      188          ADD   R15,#SIZEOF COM_MSG   !RESTORE STACK STATE!
003E 9E08            189          RET
0040                 190      END MM_CREATE_ENTRY
                     191 !PAGE
```

```
!
0040                    192     MM_DELETE_ENTRY                 PROCEDURE
                        193         !*********************************!
                        194         ! INTERFACE BETWEEN SEG MGR      !
                        195         ! (DELETE_SEG PROCEDURE) AND     !
                        196         ! MMGR (DELETE_ENTRY PROCEDURE).!
                        197         ! ARRANGES AND PERFORMS IPC.     !
                        198         !*********************************!
                        199         ! REGISTER USE:                  !
                        200         ! PARAMETERS                     !
                        201         !  R0:SUCCESS CODE(RET)         !
                        202         !  R1:HPTR(INPUT)               !
                        203         !  R2:ENTRY_NO(INPUT)           !
                        204         ! LOCAL USE                      !
                        205         !  R6:MM HANDLE ARRAY ENTRY     !
                        206         !  R8:^COM_MSGBUF               !
                        207         !  R13:^COM_MSGBUF              !
                        208         !*********************************!
                        209     ENTRY
0040 030F  0010         210         SUB   R15,#SIZEOF COM_MSG  !USE STACK FOR MESSAGE!
0044 A1FD               211         LD    R13,R15   ! ^COM_MSGBUF !
                        212
                        213         !FILL COM_MSGBUF (LOAD MESSAGE). DELETE_MSG FRAME
                        214          IS BASED AT ADDRESS ZERO. IT IS OVERLAID ONTO
                        215          COM_MSGBUF FRAME BY INDEXING EACH ENTRY (I.E. ADD-
                        216                  ING TO EACH ENTRY) THE BASE ADDRESS OF COM_MSGBUF!
                        217
0046 4DD5  0000         218         LD    DELETE_MSG.DELETE_CODE(R13),#DELETE_ENTRY_CODE
004A 0033
004C 3116  0000         219         LD    R6,R1(#0)  !INDEX TO MM_HANDLE ENTRY!
0050 6FD6  0002         220         LD    DELETE_MSG.DE_MM_HANDLE[0](R13),R6
0054 3116  0002         221         LD    R6,R1(#2)
0058 6FD6  0004         222         LD    DELETE_MSG.DE_MM_HANDLE[1](R13),R6
005C 3116  0004         223         LD    R6,R1(#4)
0060 6FD6  0006         224         LD    DELETE_MSG.DE_MM_HANDLE[2](R13),R6
0064 6FD2  0008         225         LD    DELETE_MSG.DE_ENTRY_NO(R13),R2
0068 A1D8               226         LD    R8,R13
                        227 !PAGE
```

```
!
00CA 5F00  01A8'     228          CALL  PERFORM_IPC  !R8: ^COM_MSGBUF!
                     229          !RETRIEVE SUCCESS_CODE FROM RETURNED MESSAGE!
006E 60D8  0002      230          LDB   RL0,RET_SUC_CODE.SUC_CODE(R13)
0072 010F  0010      231          ADD   R15,#SIZEOF COM_MSG   !RESTORE STACK STATE!
0076 9E08            232          RET
0078                 233      END MM_DELETE_ENTRY
                     234 !PAGE
```

```
                                    !
007E                        235     MM_ACTIVATE          PROCEDURE
                            236         !*********************************!
                            237         ! INTERFACE BETWEEN SEG MGR      !
                            238         ! (MAKE_KNOWN PROCEDURE) AND     !
                            239         ! MMGR   (ACTIVATE PROCEDURE).   !
                            240         ! ARRANGES AND PERFORMS IPC.     !
                            241         !*********************************!
                            242         ! REGISTER USE:                  !
                            243         ! PARAMETERS                     !
                            244         !  R0:SUCCESS CODE(RET)         !
                            245         !  R1:DBR NO(INPUT)             !
                            246         !  R2:HPTR(INPUT)               !
                            247         !  R3:ENTRY NO                  !
                            248         !  R4:SEGMENT NO                !
                            249         ! LOCAL USE                     !
                            250         !  R8:^COM_MSGBUF               !
                            251         !  R13:^COM_MSGBUF              !
                            252         !*********************************!
                            253
                            254     ENTRY
0078 030F  0010             255         SUB   R15,#SIZEOF COM_MSG  !USE STACK FOR MESSAGE!
007C A1FD                   256         LD    R13,R15   ! ^COM_MSGBUF !
                            257
                            258         !FILL COM_MSGBUF (LOAD MESSAGE). ACTIVATE_MSG FRAME
                            259          IS BASED AT ADDRESS ZERO. IT IS OVERLAID ONTO
                            260          COM_MSGBUF FRAME BY INDEXING EACH ENTRY (I.E. ADD-
                            261          ING TO EACH ENTRY) THE BASE ADDRESS OF COM_MSGBUF!
007E 4DD5  0000             262         LD    ACTIVATE_MSG.ACTIVATE_CODE(R13),
0082 0034
                            263                                          #ACTIVATE_SEG_CODE
0084 6ED9  0002             264         LDB   ACTIVATE_MSG.A_DBR_NO(R13),RL1
0088 3126  0000             265         LD    R6,R2(#0)
008C 6FD6  0004             266         LD    ACTIVATE_MSG.A_MM_HANDLE[0](R13),R6
0090 3126  0002             267         LD    R6,R2(#2)
0094 6FD6  0006             268         LD    ACTIVATE_MSG.A_MM_HANDLE[1](R13),R6
0098 3126  0004             269         LD    R6,R2(#4)
                            270 !PAGE
```

```
!
ØØ9C 6FD6  ØØØ8        LD    ACTIVATE_MSG.A_MM_HANDLE[2](R13),R6
ØØAØ 6EDB  ØØØA        LDB   ACTIVATE_MSG.A_ENTRY_NO(R13),RI3
ØØA4 6EDC  ØØØB        LDB   ACTIVATE_MSG.A_SEGMENT_NO(R13),RL4
ØØA8 A1D8              LD    R8,R13
ØØAA 93F4              PUSH  @R15,R4  !SAVE COPY SEG #!
ØØAC 5FØØ  Ø1A8'       CALL  PERFORM_IPC !(R8:^COM_MSGBUF!

                       !UPDATE KST MM_HANDLE ENTRY!
ØØBØ 21Ø1  ØØØ2        LD    R1,#KST_SEG_NO
ØØB4 5FØØ  ØØØØ*       CALL  ITC_GET_SEG_PTR !(R1:KST_SEG_NO,RET:RØ:^KST)!
ØØB8 A1ØC              LD    R12,RØ  !^KST!
ØØBA 97F4              POP   R4,@R15 !SEG #!
ØØBC A145              LD    R5,R4 !MOVE SEG # TO ALLOW MULT!
ØØBE Ø3Ø5  ØØØA        SUB   R5,#NR_OF_KSEGS !CONVERT TO INDEX!
ØØC2 19Ø4  ØØ1Ø        MULT  RR4,#SIZEOF KST_REC !OFFSET IN KST TO SEG REC!
ØØC6 815C              ADD   R12,R5 !ADD OFFSET TO ^KST!
ØØC8 61D6  ØØØ2        LD    R6,R_ACTIVATE_ARG.R_MM_HANDLE[Ø](R13)
ØØCC 6FC6  ØØØØ        LD    KST.MM_HANDLE[Ø](R12),R6
ØØDØ 61D6  ØØØ4        LD    R6,R_ACTIVATE_ARG.R_MM_HANDLE[1](R13)
ØØD4 6FC6  ØØØ2        LD    KST.MM_HANDLE[1](R12),R6
ØØD8 61D6  ØØØ6        LD    R6,R_ACTIVATE_ARG.R_MM_HANDLE[2](R13)
ØØDC 6FC6  ØØØ4        LD    KST.MM_HANDLE[2](R12),R6
                       !RETRIEVE OTHER RETURN ARGUMENTS!
ØØEØ 6ØD8  ØØØØ        LDB   RLØ,R_ACTIVATE_ARG.R_SUC_CODE(R13)
ØØE4 54D2  ØØØ8        LDL   RR2,R_ACTIVATE_ARG.R_CLASS(R13)
ØØE8 61D4  ØØØC        LD    R4,R_ACTIVATE_ARG.R_SIZE(R13)
ØØEC Ø1ØF  ØØ1Ø        ADD   R15,#SIZEOF COM_MSG !RESTORE STACK STATE!
ØØFØ 9E Ø8             RET
ØØF2               END MM_ACTIVATE
               !PAGE
```

```
                    !
00F2                301     MM_DEACTIVATE                   PPOCEDURE
                    302         !*********************************!
                    303         ! INTERFACE BETWEEN SEG MGR      !
                    304         ! (TERMINATE PROCEDURE) AND      !
                    305         ! MMGR (DEACTIVATE PROCEDURE).   !
                    306         ! ARRANGES AND PERFORMS IPC.     !
                    307         !*********************************!
                    308         ! REGISTER USE:                  !
                    309         ! PARAMETERS                     !
                    310         !  R0:SUCCESS CODE(RET)          !
                    311         !  R1:DBR NO(INPUT)              !
                    312         !  R2:EPTR(INPUT)                !
                    313         ! LOCAL USE                      !
                    314         !  R6:MM HANDLE ARRAY ENTRY      !
                    315         !  R8:^COM_MSGBUF                !
                    316         !  R13:^COM_MSGBUF               !
                    317         !*********************************!
                    318
                    319     ENTRY
00F2 030F  0010     320         SUB   R15,#SIZEOF COM_MSG  !USE STACK FOR MESSAGE!
00F6 A1FD           321         LD    R13,R15   ! ^COM_MSGBUF !
                    322
                    323         !FILL COM_MSGBUF (LOAD MESSAGE). DEACTIVATE_MSG FRAME
                    324          IS BASED AT ADDRESS ZERO. IT IS OVERLAID ONTO
                    325          COM_MSGBUF FRAME BY INDEXING EACH ENTRY (I.E. ADD-
                    326          ING TO EACH ENTRY) THE BASE ADDRESS OF COM_MSGBUF!
                    327
00F8 4DD5  0002     328         LD    DEACTIVATE_MSG.DEACTIVATE_CODE(R13),
00FC 0035
                    329                                   #DEACTIVATE_SEG_CODE
00FE 6ED9  0002     330         LDB   DEACTIVATE_MSG.D_DBR_NO(R13),RL1
0102 312E  0000     331         LD    R6,R2(#0)  !INDEX TO MM_HANDLE ENTRY!
0106 6FDE  0004     332         LD    DEACTIVATE_MSG.D_MM_HANDLE[0](R13),R6
010A 312E  0002     333         LD    R6,R2(#2)
010E 6FDE  0006     334         LD    DEACTIVATE_MSG.D_MM_HANDLE[1](R13),R6
0112 312E  0004     335         LD    R6,R2(#4)
                    336 !PAGE
```

```
                        !
0110 6FD6  0008         337         LD    DEACTIVATE_MSG.D_MM_HANDLE[2](R13),R6
011A A1D8               338         LD    R8,R13
011C 5F00  01A8'        339         CALL  PERFORM_IPC  !R8: ^COM_MSGBUF!
                        340
                        341         !RETRIEVE SUCCESS_CODE FROM RETURNED MESSAGE!
                        342
0120 6BD8  0000         343         LDB   RL0,RET_SUC_CODE.SUC_CODE(R13)
0124 810F  0010         344         ALD   R15,#SIZEOF COM_MSG   !RESTORE STACK STATE!
0128 9E08               345         RET
012A                    346     END MM_DEACTIVATE
                        347 !PAGE
```

```
                                !
012A                    348     MM_SWAP_IN                      PROCEDURE
                        349         !*********************************!
                        350         ! INTERFACE BETWEEN SEG MGR (SM_ !
                        351         ! SWAP_IN PROCEDURE) AND MMGR    !
                        352         ! (SWAP_IN PROCEDURE). ARRANGES  !
                        353         ! AND PERFORMS IPC.              !
                        354         !*********************************!
                        355         ! REGISTER USE:                  !
                        356         ! PARAMETERS                     !
                        357         !  R0:SUCCESS_CODE(RET)         !
                        358         !  R1:DBR_NO(INPUT)             !
                        359         !  R2:EPTR(INPUT)               !
                        360         !  R3:ACCESS_MODE(INPUT)        !
                        361         ! LOCAL USE                      !
                        362         !  R6:MM_HANDLE ARRAY ENTRY     !
                        363         !  R8:^COM_MSGBUF               !
                        364         !  R13:^COM_MSGBUF              !
                        365         !*********************************!
                        366     ENTRY
012A 030F  0010         367         SUB   R15,#SIZEOF COM_MSG  !USE STACK FOR MESSAGE!
012F A1FD               368         LD    R13,R15   ! ^COM_MSGBUF !
                        369
                        370         !FILL COM_MSGBUF (LOAD MESSAGE). SWAP_IN_MSG FRAME
                        371          IS BASED AT ADDRESS ZERO. IT IS OVERLAID ONTO
                        372          COM_MSGBUF FRAME BY INDEXING EACH ENTRY (I.E. ADD-
                        373          ING TO EACH ENTRY) THE BASE ADDRESS OF COM_MSGBUF!
                        374
0130 4DD5  0000         375         LD    SWAP_IN_MSG.SWAP_IN_CODE(R13),#SWAP_IN_SEG_CODE
0134 0036
0136 3126  0000         376         LD    R6,R2(#0)  !INDEX TO MM_HANDLE ENTRY!
013A 6FD6  0002         377         LD    SWAP_IN_MSG.SI_MM_HANDLE[0](R13),R6
013E 3126  0002         378         LD    R6,R2(#2)
0142 6FD6  0004         379         LD    SWAP_IN_MSG.SI_MM_HANDLE[1](R13),R6
0146 3126  0004         380         LD    R6,R2(#4)
014A 6FD6  0006         381         LD    SWAP_IN_MSG.SI_MM_HANDLE[2](R13),R6
014F 6FD9  0008         382         LDB   SWAP_IN_MSG.SI_DBR_NO(R13),RL1
                        383 !PAGE
```

```
!
0152 6ED3  0009      384          LDB   SWAP_IN_MSG.SI_ACCESS_AUTH(R13),RL3
0156 A1D8            385          LD    R8,R13
0158 5F00  01A8'     386          CALL  PERFORM_IPC  !R8: ^COM_MSGBUF!
                     387          !RETRIEVE SUCCESS_CODE FROM RETURNED MESSAGE!
015C 60D8  0000      388          LDB   RL0,RET_SUC_CODE.SUC_CODE(R13)
0160 010F  0010      389          ADD   R15,#SIZEOF COM_MSG   !RESTORE STACK STATE!
0164 9E08            390          RET
0166                 391      END MM_SWAP_IN
                     392 !PAGE
```

```
                    !
0166                393     MM_SWAP_OUT                         PROCEDURE
                    394         !*************************************!
                    395         ! INTERFACE BETWEEN SEG MGR (SM_    !
                    396         ! SWAP_OUT PROCEDURE) AND MMGR      !
                    397         ! (SWAP_OUT PROCEDURE). ARRANGES    !
                    398         ! AND PERFORMS IPC.                 !
                    399         !*************************************!
                    400         ! REGISTER USE:                     !
                    401         ! PARAMETERS                        !
                    402         !  R0:SUCCESS_CODE(RET)            !
                    403         !  R1:DBR_NO(INPUT)                !
                    404         !  R2:HPTR(INPUT)                  !
                    405         ! LOCAL USE                         !
                    406         !  R6:MM_HANDLE_ARRAY_ENTRY        !
                    407         !  R8:^COM_MSGBUF                  !
                    408         !  R13:^COM_MSGBUF                 !
                    409         !*************************************!
                    410     ENTRY
0166 030F  0010     411         SUB   R15,#SIZEOF COM_MSG  !USE STACK FOR MESSAGE!
016A A1FD           412         LD    R13,R15   ! ^COM_MSGBUF !
                    413
                    414         !FILL COM_MSGBUF (LOAD MESSAGE). SWAP_OUT_MSG FRAME
                    415          IS BASED AT ADDRESS ZERO. IT IS OVERLAID ONTO
                    416          COM_MSGBUF FRAME BY INDEXING EACH ENTRY (I.E. ADD-
                    417          ING TO EACH ENTRY) THE BASE ADDRESS OF COM_MSGBUF!
                    418
016C 4DD5  0000     419         LD    SWAP_OUT_MSG.SWAP_OUT_CODE(R13),
0170 0037
                    420                                       #SWAP_OUT_SEG_CODE
0172 3126  0000     421         LD    R6,R2(#0)  !INDEX TO MM_HANDLE ENTRY!
0176 6FD6  0004     422         LD    SWAP_OUT_MSG.SO_MM_HANDLE[0](R13),R6
017A 3126  0002     423         LD    R6,R2(#2)
017E 6FD6  0006     424         LD    SWAP_OUT_MSG.SO_MM_HANDLE[1](R13),R6
0182 3126  0004     425         LD    R6,R2(#4)
0186 6FD6  0008     426         LD    SWAP_OUT_MSG.SO_MM_HANDLE[2](R13),R6
018A 6ED9  0002     427         LDB   SWAP_OUT_MSG.SO_DBR_NO(R13),R11
                    428 !PAGE
```

```
!
018E A1D8                429          LD     R8,R13
0190 5F00  01A8'         430          CALL   PERFORM_IPC  !R8: ^COM_MSGBUF!
                         431          !RETRIEVE SUCCESS_CODE FROM RETURNED MESSAGE!
0194 60D8  0000          432          LDF    RL0,RET_SUC_CODE.SUC_CODE(R13)
0198 010F  0010          433          ADD    R15,#SIZEOF COM_MSG    !RESTORE STACK STATE!
019C 9E08                434          RET
019E                     435      END MM_SWAP_OUT
                         436 !PAGE
```

```
!
019E                    437     MM_GET_DBR_VALUE                PROCEDURE
                        438         !*********************************!
                        439         ! RETRIEVES DBR VALUE (ADDRESS   !
                        440         ! OF MMU REC POINTED TO BY DBR_  !
                        441         ! NO)                            !
                        442         !*********************************!
                        443         ! REGISTER USE:                  !
                        444         !  R1:DBR NO (INPUT)            !
                        445         !  R2:DBR VALUE (RET)           !
                        446         !*********************************!
                        447
                        448     ENTRY
019E 1900  0100         449         MULT  RR0,#SIZEOF MMU
01A2 7612  0000*        450         LDA   R2,MMU_IMAGE(R1)
01A6 9E08               451         RET
01A8                    452     END MM_GET_DBR_VALUE
                        453
                        454 !PAGE
```

```
                        !
01A8                    PERFORM_IPC                     PROCEDURE
                        !*************************************!
                        ! SERVICE ROUTINE TO ARRANGE AND      !
                        ! PERFORM IPC WITH THE MEM MGR PROC   !
                        !*************************************!
                        ! REGISTER USE:                       !
                        ! PARAMETERS                          !
                        !  R8: ^COM_MSG(INPUT)                !
                        ! LOCAL USE                           !
                        !  R1,R2: WORK REGS                   !
                        !  R4: ^G_AST_LOCK                    !
                        !  R13: ^COM_MSGBUF                   !
                        !*************************************!

                        ENTRY
01AE 93FD               PUSH  @R15,R13  !^COM_MSGBUF!
01AA 5F00  0000*        CALL  ITC_GET_CPU_NO !RET-R1:CPU_NO!
01AE A112               LD    R2,R1
01B0 6121  0000'        LD    R1,MM_CPU_TABLE(R2)  !MM_VP_ID!
01B4 7604  0002*        LDA   R4,G_AST_LOCK
01B8 5F00  0000*        CALL  K_LOCK
01BC 5F00  0000*        CALL  SIGNAL  !R1:MM_VP_ID,R8:^COM_MSGBUF!
01C0 97FD               POP   R13,@R15
01C2 A1D8               LD    R8,R13  !^COM_MSGBUF!
01C4 93FD               PUSH  @R15,R13
01C6 5F00  0000*        CALL  WAIT  !R8:^COM_MSGBUF!
01CA 7604  0000*        LDA   R4,G_AST_LOCK
01CE 5F00  0000*        CALL  K_UNLOCK
01D2 97FD               POP   R13,@R15
01D4 9E0E               RET
01D6                    END PERFORM_IPC

                        END DIST_MM

                    !PAGE
```

APPENDIX E - NON-DISCRETIONARY SECURITY PL/SYS LISTINGS

```
NDS MODULE


CONSTANT
        TRUE            := 1
        FALSE           := 0

TYPE
        ACCESS_CLASS            RECORD [ LEVEL  INTEGER
                                         CAT    INTEGER ]
        CPTR                    ^ACCESS_CLASS

INTERNAL
        CLASS1_PTR              CPTR
        CLASS2_PTR              CPTR
        CATS_REL                INTEGER

GLOBAL

!*****************************************************************
*                                                                *
*     CLASS_EQ PROCEDURE. INVOKED BY VARIOUS KERNEL              *
*     PROCEDURES. COMPARES TWO CLASSIFICATIONS (LABELS)          *
*     AND DETERMINES IF THEIR RELATIONSHIP IS EQUAL.             *
*     RETURNS A TRUE/FALSE CONDITION_CODE.                       *
*                                                                *
*****************************************************************!

CLASS_EQ PROCEDURE  ( CLASS1          LONG
                      CLASS2          LONG )
         RETURNS    ( CONDITION_CODE BYTE )

ENTRY
    IF CLASS1 = CLASS2 THEN
        CONDITION_CODE := TRUE
    ELSE
        CONDITION_CODE := FALSE
    FI
    RETURN
END CLASS_EQ
```

```
!*****************************************************************************
*                                                                             *
*     CLASS_GE PROCEDURE. CALLED BY VARIOUS KERNEL                            *
*     PROCEDURES. COMPARES TWO CLASSIFICATIONS (CLASS1                        *
*     AND CLASS2) AND DETERMINES IF LABEL1 IS GREATER                         *
*     THAN OR EQUAL TO CLASS2. RETURNS TRUE/FALSE CONDI-                      *
*     TION CODE.                                                              *
*                                                                             *
*****************************************************************************!


CLASS_GE PROCEDURE    ( CLASS1          LONG
                        CLASS2          LONG )
         RETURNS      ( CONDITION_CODE BYTE )

ENTRY
    ! TYPE CONVERSION TO ALLOW OPERATIONS ON THE 16 MOST !
    ! AND 16 LEAST SIGNIFICANT BITS OF EACH CLASS. THE   !
    ! 16 MSBITS ARE THE CLASS LEVEL AND THE 16 LSBITS    !
    ! ARE THE CLASS CATEGORY (CAT).                      !

    CLASS1_PTR := CPTR #CLASS1
    CLASS2_PTR := CPTR #CLASS2
    ! COMPARE CATEGORIES (SET COMPARISON); SEE IF CAT2   !
    ! IS A SUBSET OF CAT1.                               !
    CATS_REL := CLASS1_PTR^.CAT OR CLASS2_PTR^.CAT
    IF CATS_REL = CLASS1_PTR^.CAT   ! THEN CAT2 IS SUBSET !
    ANDIF CLASS1_PTR^.LEVEL >= CLASS2_PTR^.LEVEL THEN
    ! LEVEL COMPARISON IS SIMPLE NUMERICAL COMPARISON !
        CONDITION_CODE := TRUE
    ELSE
        CONDITION_CODE := FALSE
    FI
    RETURN
END CLASS_GE
END NDS
```

```
                                  !
                                    2 !   APPENDIX F - NON-DISCRETIONARY SECURITY PLZ/ASM LISTING
                                    3 !
                                    4     NDS MODULE
                                    5     CONSTANT
                                    6             TRUE            :=1
                                    7             FALSE           :=0
                                    8     INTERNAL
                                    9     $SECTION ACC_CLASS_LCI !NOTE: IS AN OVERLAY, IE NO
                                   10                            ALLOCATION OF MEMORY!
                                   11     $ABS 0
0000                               12     ACCESS_CLASS        RECORD [LEVEL   INTEGER
                                   13                                 CAT     INTEGER]
                                   14
                                   15     GLOBAL
                                   16     $SECTION NDS_PROC
0000                               17     CLASS_EQ PROCEDURE
                                   18
                                   19 !*****************************************!
                                   20 !  PASSED PARAMETERS                      !
                                   21 !    RR2 = CLASS1                         !
                                   22 !    RR4 = CLASS2                         !
                                   23 !  RETURNED                               !
                                   24 !    R1 = CONDITION CODE                  !
                                   25 !*****************************************!
                                   26
                                   27     ENTRY
0000 9042                          28         CPL     RR2,RR4
0002 5E0E  000E'                   29         IF      EQ      THEN
0006 2101  0001                    30                 LD      R1,#TRUE
000A 5E06  0012'                   31         ELSE
000E 2101  0000                    32                 LD      R1,#FALSE
                                   33         FI
0012 9E0E                          34     RET
0014                               35     END CLASS_EQ
                                   36 !PAGE
```

```
!
0014                    37      CLASS_GE PROCEDURE
                        38
                        39 !*****************************************!
                        40 !  PASSED PARAMETERS                      !
                        41 !    RR2 = CLASS1                         !
                        42 !    RR4 = CLASS2                         !
                        43 !  RETURNED PARAMETER                     !
                        44 !    R1 = CONDITION CODE                  !
                        45 !*****************************************!
                        46
                        47      ENTRY
0014 91F2               48          PUSHL @R15,RR2 !PUSH CLASS1 ON STACK--REFER BY ADDR!
0016 A1FD               49          LD    R13,R15  ! CLASS1 ADDR !
0018 91F4               50          PUSHL @R15,RR4
001A A1FF               51          LD    R14,R15  ! CLASS2 ADDR !
001C 31F7  0002         52          LD    R7,R14(#ACCESS_CLASS.CAT)   ! CAT2 IN R7 !
0020 45D7  0002         53          OR    R7,ACCESS_CLASS.CAT(R13) !CAT1 OR CAT2, R7!
0024 4BD7  0002         54          CP    R7,ACCESS_CLASS.CAT(R13) !CAT1=(CAT1 OR CAT2)?!
0028 5E0E  0048'        55          IF EQ THEN
002C 61D6  0006         56             LD   R6,ACCESS_CLASS.LEVEL(R13) !LEVEL1!
                        57                  ! COMPARE LEVEL1 WITH LEVEL2 !
0030 4BE6  0000         58             CP   R6,ACCESS_CLASS.LEVEL(R14)
0034 5EC1  0040'        59             IF   GE      THEN    ! LEVEL1 GE LEVEL2 !
0038 2101  0001         60                  LD      R1,#TRUE
003C 5E08  0044'        61             ELSE
0040 2101  0000         62                  LD      R1,#FALSE
                        63             FI
0044 5E08  004C'        64          ELSE
0048 2101  0000         65             LD   R1,#FALSE
                        66          FI
004C 95F4               67          POPL    RR4,@R15
004E 95F2               68          POPL    RR2,@R15  !RESTORE STACK!
0050 9E08               69          RET
0052                    70      END CLASS_GE
                        71      END NLS
                        72 !PAGE
```

APPENDIX G - SUMMARY OF REFINEMENTS

The following new procedures were added to the Inner Traffic Controller:

(1) ITC_GET_CPU_NO procedure. This procedure locates and returns the current CPU number (identification). It was used in segment management by the distributed memory manager to index into the MM_CPU_TABLE to find the memory manager process VP_ID for the current processor. This VP_ID was, in turn, used as an argument in the call to SIGNAL.

(2) ITC_GET_SEG_PTR procedure. This service procedure uses an input segment number to search the MMU_IMAGE to find the base address (pointer) for that segment. It was used in segment management to find the base address of the segment used in a process for its KST.

(3) K_LOCK and K_UNLOCK procedures. These procedures were implemented to indicate the intention to eventually have a kernel wait-lock system. K_LOCK simply calls SPIN_LOCK in its present design.

The following changes were made to the Inner Traffic Controller:

(1) The provision for a "jump table" was removed when a working version of the linker was introduced. This involved removing the constant TC_PREEMPT_HANDLER and adding an "external" declaration for the TC_PREEMPT_HANDLER Procedure.

(2) Minor changes were necessary in three procedures to modify the message size from one word to a sixteen byte array (minor changes were also needed in the declaration section). The procedures effected were: ENTER_MSG_LIST, GET_FIRST_MSG, and WAIT. The changes are documented in the code for each procedure.

The following procedures were added to the Traffic Controller:

(1) TC_GET_PROC_CLASS Procedure. This procedure locates and returns the current process's classification (i.e., it retrieves the SAC entry from the APT). It was used in Segment management to retrieve the PROC_CLASS for the Segment Manager.

(3) TC_GET_DBR_NO Procedure. This procedure returns the current DBR_NO value from the APT. The Segment Manager used this procedure to obtain the DBR_NO to pass to the memory manager.

The version of the Traffic Controller shown in Appendix H is a "stub" of Reitz' [9] actual work. This stub contains the elements of the TC Module needed for proper operation of the segment management demonstration.

APPENDIX H - SEGMENT MANAGEMENT DEMONSTRATION

A. DESCRIPTION

The Seg_Mgr.Demo, as stated before, is built onto Reitz' Sync.Demo (which was designed for a different purpose than segment management, obviously). The functions illustrated by the present demonstration are: (1) virtual processor synchronization and (2) segment management function performance. The listings of the modules involved are in appendices A-F and I. It is suggested that the ASM versions be used as references; PIZ/SYS versions served as "pseudo-code" during detailed design, but are untested. The narrative discussion of the demonstration context and sequence is presented below. The output generated at each process entry point will identify the signaller in each case and the action the current process takes. The following actions are illustrated (viz., "simulated") in this demonstration. Note that this simulation uses the ITC SIGNAL/WAIT primitives instead of the TC ADVANCE/AWAIT primitives that are not yet implemented.

1. An I/C interrupt signals the IO process that a packet from the host is ready. The IO process is scheduled; it reads the packet (output: "IC: Receive Command") and signals the FM process (output: "IC: Signal FM (Create)"), passing the command (CREATE is

simulated). The IO process calls Wait, thus blocking itself while waiting for a signal from the FM process.

2. The FM process is scheduled (output: "IO=Signaller"); it interprets the command (simulated) as CREATE and thus calls CREATE_SEG in the Segment Manager (output: "FM: Call Kernel(Create)"). The normal input arguments for CREATE_SEG are passed in this call.

3. CREATE_SEG validates the CREATE request and then calls MM_CREATE_ENTRY in the Distributed Memory Manager.

4. MM_CREATE_ENTRY signals the memory manager process (MM process) and calls WAIT, thus blocking itself while waiting for a signal from the MM process.

5. The MM process is scheduled (output: "Kernel=Signaller (for FM)"); the mainline code interprets the function code and calls the CREATE_ENTRY procedure for action. When action is complete (output: "MM: CREATE_ENTRY"), the procedure returns to the mainline code. The MM process signals the return success code in a message to the FM process, then calls WAIT to wait for the next signal.

6. The FM process is scheduled (output: "Return from

Kernel"). The FM process then signals completion of CREATE to the IO process and calls WAIT (output: "FM: Signal IO").

7. The IO process is scheduled (output: "FM=Signaller"). It signals the FM process to cause a "read" to occur, i.e., the same pattern as in steps b. through e. occur for MAKE_KNOWN and SWAP_IN prior to the FM process signalling back to the IO process that the "read" was completed. This "read" is defined strictly for this test and is not equivalent to a typical Read_File packet.

8. The IO process will then be again scheduled and will perform the same functions as did the FM process (i.e., will call MAKE_KNOWN and SM_SWAP_IN sequentially) for the same segment.

9. The IO process will again be scheduled and will signal the FM process to perform the same sequence as described in g. for SM_SWAP_OUT and TERMINATE.

10. The IO process will again be scheduled and will repeat step h. with SM_SWAP_OUT and TERMINATE.

11. The IO process will again be scheduled and will cause the FM process to repeat steps b. through e. to delete (DELETE_SEG called) the segment.

12. The entire loop repeats forever.

E. INITIALIZATION

The description of the intialization of the databases is presented in figures containing the appropriate memory data. Reference to the previous descriptions of these databases and the type declarations will be useful. Figure 9 is the initialized Active Process Table. Figure 10 is the initialized Virtual Processor Table. Figure 11 is partial representation of the initialized KST for the FM process (9300) and the IO process (9700). Figure 12 is partial representation of the initialized MMU_IMAGE. Figure 13 is partial representation of the initialized process stack segments. Figure 14 is the corresponding link command line and response, and the Imager command line and response. Figure 15 is the load command lines and response, and the register initializations. Figure 16 is the output (as displayed on the CRT screen) generated by the demonstration.

```
!
!           APPENDIX I - DEMONSTRATION LISTINGS

          INNER_TRAFFIC_CONTROL MODULE

        !** 1. GETWORK:
              A. NORMAL ENTRY DOES NOT SAVE REGISTERS.
                ( THIS IS A FUNCTION OF THE GATEKEEPER ).
              C. R14 IS AN INPUT PARAMETER TO GETWORK THAT
                 SIMULATES INFO THAT WILL EVENTUALLY BE ON
                 THE MMU HARDWARE.  THIS REGISTER MUST BE
                 ESTABLISHED AS A DBR BY ANY PROCEDURE
                 INVOKING GETWORK.
              D. PREEMPT INTERRUPT ENTRY HANDLER, WHICH IS
                 CONTAINED IN GETWORK, DOES NOT USE THE
                 GATEKEEPER AND MUST  PERFORM FUNCTIONS
                 NORMALLY ACCOMPLISHED BY IT
                 PRIOR TO NORMAL ENTRY AND EXIT.
                 ( SAVE/RESTORE: REGS, NSP; UNLOCK VPT,
                       TEST INT)
            2. GENERAL:
              A. ALL VIOLATIONS OF
                 VIRTUAL MACHINE INSTRUCTIONS ARE CONSIDERED
                 ERROR CONDITIONS AND WILL RETURN SYSTEM TO
                 MONITOR WITH ERROR CODE IN R0 AND PC IN R1.
              B. ITC PROCEDURES CALLING GETWORK PASS DBR
                 (REGISTER R14) AS INPUT PARAMETER.
                 ( INCLUDES: SIGNAL, WAIT, SWAP_VDBR, AND
                   IDLE).                                **!
!PAGE
```

```
35              CONSTANT
36               ! ********** ERROR CODES ********** !
37                UNAUTH_LOCK                 := 0
38                MSG_LIST_EMPTY              := 1
39                MSG_LIST_ERROR              := 2
40                READY_LIST_EMPTY            := 3
41                MSG_LIST_OVERFLOW           := 4
42                SWAP_NOT_ALLOWED            := 5
43                VP_INDEX_ERROR              := 6
44
45
46               ! ******** SYSTEM PARAMETERS ******** !
47                  NR_MMU_REG       := 64    !LONG WORDS!
48                  NR_VP            := 4
49                  IDLE_VP          := NR_VP-1
50                  STACK_SEG        := 1
51                  STACK_SEG_SIZE   := %100
52                    ! * * OFFSETS IN STACK SEG * * !
53                  STACK_BASE       := STACK_SEG_SIZE-%40
54                  STATUS_REG_BLOCK:= STACK_SEG_SIZE-%40
55                  F_C_W            := STACK_SEG_SIZE-%20
56                  PROCESS_ID       := STACK_SEG_SIZE-%1E
57                  N_S_P            := STACK_SEG_SIZE-%1C
58                  ON       := %FFFF
59                  OFF      := 0
60                  RUNNING  := 0
61                  READY    := 1
62                  WAITING  := 2
63                  NIL      := %FFFF
64                  INVALID  := %FFEF
65                  MONITOR   := %A900        ! HBUG ENTRY !
66 !PAGE
```

```
67              TYPE
68                 MESSAGE           ARRAY [16   BYTE]
69                 ADDRESS           WORD
70                 VP_INDEX          INTEGER
71                 MSG_INDEX         INTEGER
72
73                 MMU_TABLE RECORD [ BASE  ADDRESS
74                      ATTRIBUTES  WORD
75                    ]
76               MSG_TABLE RECORD
77                  [ MSG            MESSAGE
78                    SENDER         VP_INDEX
79                    NEXT_MSG       MSG_INDEX
80                    FILLER         ARRAY [6, WORD]
81                  ]
82
83              VP_TABLE RECORD
84                  [ DBR            ADDRESS
85                    PRI            WORD
86                    STATE          WORD
87                    IDLE_FLAG      WORD
88                    PREEMPT        WORD
89                    PHYS_PROCESSOR  WORD
90                    NEXT_READY_VP  VP_INDEX
91                    MSG_LIST       MSG_INDEX
92                    FILLER_1       ARRAY [8, WORD]
93                ]
94
95              EXTERNAL
96                TC_PREEMPT_HANLLER          PROCEDURE
97
98  !PAGE
```

```
!
                99          INTERNAL
               100          $SECTION ITC_DATA
0000           101             VPT       RECORD
               102               [ LOCK             WORD
               103                 RUNNING_LIST VP_INDEX
               104                 READY_LIST   VP_INDEX
               105                 FREE_LIST    MSG_INDEX
               106                 FILLER_2     ARRAY [4, WORD]
               107                 VP           ARRAY [NR_VP, VP_TABLE]
               108                 MSG_Q        ARRAY [NR_VP, MSG_TABLE]
               109               ]
               110 !PAGE
```

```
!
                        111             $SECTION ITC_INT_PROC
0000                    112             GETWORK     PROCEDURE
                        113                 !*********************************!
                        114                 ! SWAPS VIRTUAL PROCESSORS       !
                        115                 ! ON PHYSICAL PROCESSOR.         !
                        116                 !*********************************!
                        117                 ! REGISTER USE:                  !
                        118                 !  STATUS REGISTERS             !
                        119                 !   R0: INTERRUPT_RETURN_FLAG   !
                        120                 !   R14: DBR (SIMULATION)       !
                        121                 !   R15: STACK_POINTER          !
                        122                 !  LOCAL VARIABLES:             !
                        123                 !   R1: READY_VP (NEW)          !
                        124                 !   R2: CURRENT_VP (OLD)        !
                        125                 !   R3: FLAG CONTROL WORD       !
                        126                 !   R4: STACK_SEG_BASE_ADDR     !
                        127                 !   R5: STATUS_REG_BLOCK_ADDR   !
                        128                 !   R6: NORMAL_STACK_POINTER    !
                        129                 !*********************************!
                        130              ENTRY
                        131              ! TURN OFF PREEMPT_RETURN_FLAG !
0000 2100  0000         132               LD        R0, #OFF
                        133
                        134              ! GET STACK BASE !
0004 31E4  0004         135               LD        R4, R14(#STACK_SEG*4)
0008 3445  00C0         136               LDA       R5, R4(#STATUS_REG_BLOCK)
                        137
                        138             ! SKIP PREEMPT_HANDLER !
000C E817               139               JR        END_PREEMPT_HANDLER
                        140
                        141              PREEMPT_ENTRY:     ! GLOBAL LABEL !
                        142              ! * * PREEMPT_HANDLER * * !
                        143
                        144 !PAGE
```

```
                                145                 ! SET DBR !
000E 6102  0002'                146                   LD        R2, VPT.RUNNING_LIST
0012 612E  0010'                147                   LD        R14, VPT.VP.DBR(R2)
                                148
                                149                 ! PUT CURRENT PROCESS IN READY STATE !
0016 4D25  0014'                150                   LD        VPT.VP.STATE(R2), #READY
001A 0001
                                151
                                152                 ! SAVE ALL REGISTERS !
001C 030F  0020                 153                   SUB       R15, #32
0020 1CF9  010F                 154                   LDM       @R15, R1, #16
                                155
                                156                 ! SAVE NORMAL STACK POINTER (NSP) !
0024 7D67                       157                   LDCTL R6, NSP
0026 93F6                       158                   PUSH @R15, R6
                                159                 ! SAVE LAST STATUS REGS !
                                160                 !NOTE:SINCE PROCESSES CAN BE PREEMPTED ANYWHERE
                                161                    IT IS NECESSARY TO HANDLE RECURSIVE CALLS
                                162                    TO GETWORK. BY SAVING THE MOST RECENT SP
                                163                    AND IRET FLAGS (R15 & R6) ON THE STACK
                                164                    THE CONTEXT OF THESE STATUS REGISTERS IS
                                165                    MAINTAINED TO ANY DEPTH OF RECURSION. !
                                166
                                167                 ! GET STACK BASE !
0028 31E4  0004                 168                   LD        R4, R14(#STACK_SEG*4)
002C 3445  00C0                 169                   LDA       R5, R4(#STATUS_REG_BLOCK)
                                170
                                171                 ! SAVE LAST STATUSS REGS !
0030 1C51  0701                 172                   LDM       R7, @R5, #2
0034 93F7                       173                   PUSH      @R15, R7
0036 93F8                       174                   PUSH      @R15, R8
                                175
                                176 !PAGE
```

```
                                !
                        177                ! SET INTERRUPT RETURN FLAG !
003E 2100  FFFF         178                  LD        R0, #ON
                        179              ! * * * * * * * * * * * !
                        180              END_PREEMPT_HANDLER:
                        181
                        182              ! GET READY_VP LIST !
003C 6101  0034'        183                LD        R1, VPT.READY_LIST
                        184
                        185              SELECT_VP:
                        186              DO  ! UNTIL ELGIBLE READY_VP FOUND !
                        187
0040 4D11  0016'        188                CP        VPT.VP.IDLE_FLAG(R1), #ON
0044 FFFF
0046 5F0F  005C'        189                IF EQ  ! VP IS IDLE ! THEN
004A 4D11  0018'        190                    CP VPT.VP.PREEMPT(R1), #ON
004E FFFF
0050 5F0F  0058'        191                    IF EQ  ! PREEMPT INTERRUPT IS ON !  THEN
0054 5E28  0068'        192                     EXIT FROM SELECT_VP
                        193                    FI
005E 5E08  0060'        194                 ELSE ! VP NOT IDLE !
005C 5E08  0068'        195                    EXIT FROM SELECT_VP
                        196                FI
                        197
                        198               ! GET NEXT READY_VP !
0060 6113  001C'        199               LD R3, VPT.VP.NEXT_READY_VP(R1)
0064 A131               200               LD R1, R3
0066 E8EC               201              OD
                        202
                        203              ! NOTE: THE READY_LIST WILL NEVER BE EMPTY SINCE
                        204                  THE IDLE VP, WHICH IS THE LOWEST PRI VP,
                        205                  WILL NEVER BE REMOVED FROM THE LIST.
                        206                  IT WILL RUN ONLY IF ALL OTHER READY VP'S ARE
                        207                  IDLING OR IF THERE ARE NO OTHER VP'S ON
                        208                  THE READY_LIST. ONCE SCHEDULED, IT
                        209                  WILL RUN UNTIL RECEIVING A HDWE INTERRUPT. !
                        212 !PAGE
```

```
                                211              ! NOTE: R14 IS USED AS DBR HERE. WHEN MMU
                                212                  IS AVAILABLE THIS SERIES OF SAVE AND LOAD
                                213                  INSTRUCTIONS WILL BE REPLACED BY SPECIAL I/O
                                214                  INSTRUCTIONS TO THE MMU. !
                                215              ! * * SAVE SP AND INTERRUPT RETURN FLAG * * !
006E 1C59  0F01                 216                LDM       @R5, R15, #2
                                217
                                218              ! * * SAVE FCW * * !
006C 7D32                       219                LDCTL     R3, FCW
006E 3343  00E0                 220                LD        R4(#F_C_W), R3
                                221
                                222              ! PLACE NEW VP IN RUNNING STATE !
0072 4D15  0014'                223                LD        VPT.VP.STATE(R1), #RUNNING
0076 0000
0078 6F01  0002'                224                LD        VPT.RUNNING_LIST, R1
                                225
                                226              ! * * SWAP DBR * * !
007C 611E  0010'                227                LD        R14, VPT.VP.DBR(R1)
                                228
                                229              ! LOAD NEW VP SP & INTERRUPT RET FLAG !
0080 31E4  0004                 230                LD        R4, R14(#STACK_SEG*4)
0084 3445  00C0                 231                LDA       R5, R4(#STATUS_REG_BLOCK)
0088 1C51  0F01                 232                LDM       R15, @R5, #2
                                233
                                234              ! * * LOAD NEW FCW * * !
008C 3143  00E0                 235                LD        R3, R4(#F_C_W)
0090 7D3A                       236                LDCTL     FCW, R3
                                237
                                238              ! TEST FOR HARDWARE INTERRUPT !
0092 0F00  FFFF                 239                CP        R0, #ON
0096 5E0E  00BC'                240                IF EQ  ! PREEMPT RETUPN ! THEN
                                241                ! HARDWARE PREEMPT INTERRUPT RETURN !
                                242
                                243                 ! UNLOCK VPT !
009A 4DC8  0000'                244                 CLR  VPT.LOCK
                                245 !PAGE
```

```
!
                                    ! TEST FOR PREEMPT !
                                     ! NOTE: SINCE A HDWE INTERRUPT DOES NOT EXIT
                                       THROUGH THE GATE, THOSE FUNCTIONS PROVIDED
                                       BY A GATE EXIT TO HANDLE PREEMPTS MUST BE
                                         PROVIDED HERE ALSO. !
009E 5F00  0106'                    CALL TEST_PREEMPT

                                    ! RESTORE LAST STATUS REGS !
00A2 97F8                           POP      R8, @R15
00A4 97F7                           POP      R7, @R15
00A6 1C59  0701                     LDM      @R5, R7, #2

                                    ! RESTORE NSP !
00AA 97F6                           POP R6, @R15
00AC 7D6F                           LDCTL   NSP, R6
                                   ! RESTORE ALL REGSTERS !
00AF 1CF1  010F                     LDM      R1, @R15, #16
00B2 010F  0020                     ADD      R15, #32

                                    ! EXECUTE HARDWARE INTERRUPT RETURN !
00B6 7B00                           IRET

00B8 5E08  00BE'                   ELSE  ! NORMAL RETURN !
00BC 9E08                           RET
                                   FI
00BF                              END GETWORK
       !PAGE
```

```
!
00BE                                ENTER MSG_LIST  PROCEDURE
                                                !*******************************!
                                                ! INSERTS POINTER TO MESSAGE    !
                                                ! FROM CURRENT_VP TO SIGNALED_VP!
                                                ! IN FIFO MSG_LIST              !
                                                !*******************************!
                                                ! REGISTER USE:                 !
                                                !  PARAMETERS:                  !
                                                !   R8(R9):MSG (INPUT)          !
                                                !   R1: SIGNALED_VP (INPUT)     !
                                                !  LOCAL VARIABLES:             !
                                                !   R2: CURRENT_VP              !
                                                !   R3: FIRST_FREE_MSG          !
                                                !   R4: NEXT_FREE_MSG           !
                                                !   R5: NEXT_Q_MSG              !
                                                !   R6: PRESENT_Q_MSG           !
                                                !*******************************!
                                    ENTRY
00BE 6102  0002'                     LD R2, VPT.RUNNING_LIST

                                    ! GET FIRST MSG FROM FREE_LIST !
00C2 6103  0006'                      LD        R3, VPT.FREE_LIST

                                                ! * * * * DEBUG * * * * !
00C6 0B03  FFFF                                 CP R3, #NIL
00CA 5E0E  00DA'                                IF EQ THEN
00CE 7621  00CE'                                 LDA R1, $
00D2 2100  0004                                  LD R0, #MSG_LIST_OVERFLOW
00D6 5F00  A900                                  CALL MONITOR
                                                FI
                                                ! * * * END DEBUG * * * !

00DA 6134  00A2'                      LD        R4, VPT.MSG_Q.NEXT_MSG(R3)
00DE 6F04  0006'                      LD        VPT.FREE_LIST, R4
                  !PAGE
```

```
!
                                ! INSERT MESSAGE LIST INFORMATION !
00E2 763A  0090'                LDA      R10,VPT.MSG_Q.MSG(R3)
00E6 2107  0010                 LD       R7,#SIZEOF MESSAGE
00EA BA81  07A0                 LDIRB    @R10,@R8,R7
00EE 6F32  00A0'                LD       VPT.MSG_Q.SENDER(R3), R2

                                ! INSERT MSG IN MSG_LIST !
00F2 6115  001E'                LD       R5, VPT.VP.MSG_LIST(R1)

00F6 0B05  FFFF                 CP       R5, #NIL
00FA 5E0E  0106'                IF EQ  ! MSG LIST IS EMPTY !  THEN
                                 ! INSERT MSG AT TOP OF LIST !
00FE 6F13  001E'                 LD      VPT.VP.MSG_LIST(R1), R3

0102 5E08  011E'                ELSE  ! INSERT MSG IN LIST !
                                 MSG_Q_SEARCH:
                                 DO  ! WHILE NOT END OF LIST !
0106 0B05  FFFF                   CP     R5, #NIL
010A 5E0E  0112'                  IF EQ  ! END OF LIST !  THEN
010E 5E08  011A'                   EXIT FROM MSG_Q_SEARCH
                                  FI

                                  ! GET NEXT LINK !
0112 A156                         LD     R6, R5
0114 6165  00A2'                  LD     R5, VPT.MSG_Q.NEXT_MSG(R6)
0118 E8F6                        OD
                                ! INSERT MSG IN LIST !
011A 6F63  00A2'                 LD      VPT.MSG_Q.NEXT_MSG(R6), R3
                                FI
011E 6F35  00A2'                LD       VPT.MSG_Q.NEXT_MSG(R3), R5
0122 9E08                       RET
0124                           END ENTER_MSG_LIST
               !PAGE
```

```
                                341  GET_FIRST_MSG      PROCEDURE
                                342                     !*********************************!
                                343                     ! REMOVES MSG FROM MSG_LIST      !
                                344                     ! AND PLACES ON FREE LIST.       !
                                345                     ! RETURNS SENDER'S MSG AND       !
                                346                     ! VP_ID                          !
                                347                     !*********************************!
                                348                     !REGISTER USE:                    !
                                349                     ! PARAMETERS:                     !
                                350                     !  R8(R9): MSG POINTER (INPUT)   !
                                351                     !  R1: SENDER VP (RETURNED)      !
                                352                     ! LOCAL VARIABLES                 !
                                353                     !  R2: CURRENT_VP                !
                                354                     !  R3: FIRST_MSG                 !
                                355                     !  R4: NEXT_MSG                  !
                                356                     !  R5: NEXT_FREE_MSG             !
                                357                     !  R6: PRESENT_FREE_MSG          !
                                358                     !*********************************!
                                359  ENTRY
0124 6102  0002'               360    LD        R2, VPT.RUNNING_LIST
                                361
                                362  ! REMOVE FIRST MSG FROM MSG_LIST !
0128 6123  001E'                363    LD        R3, VPT.VP.MSG_LIST(R2)
                                364
                                365                          ! * * * * DEBUG * * * * !
012C 0F43  FFFF                 366                          CP R3, #NIL
0130 5E0E  0142'                367                          IF EQ THEN
0134 2102  0001                 368                           LD R2, #MSG_LIST_EMPTY
0138 7601  0138'                369                           LDA R1, $
013C 5F00  A900                 370                           CALL MONITOR
                                371                          FI
                                372                          ! * * * END DEBUG * * * !
0142 6134  00A2'                373    LD        R4, VPT.MSG_Q.NEXT_MSG(R3)
0144 6F24  001E'                374    LD        VPT.VP.MSG_LIST(R2), R4
                                375  !PAGE
```

```
                                        !
                                376             ! INSERT MESSAGE IN FREE_LIST !
0148 6105  0006'                377             LD      R5, VPT.FREE_LIST
014C 0B05  FFFF                 378             CP      R5, #NIL
0150 5E0F  0162'                379             IF EQ   ! FREE_LIST IS EMPTY !  THEN
                                380              ! INSERT AT TOP OF LIST !
0154 6F03  0006'                381              LD     VPT.FREE_LIST, R3
0158 4D35  00A2'                382              LD     VPT.MSG_Q.NEXT_MSG(R3), #NIL
015C FFFF
015E 5E08  017E'                383             ELSE  ! INSERT IN LIST !
                                384              FREE_Q_SEARCH:
                                385              DO
                                386
0162 0B05  FFFF                 387               CP     R5, #NIL
0166 5F0E  016E'                388               IF EQ  ! END OF LIST !  THEN
016A 5E08  0176'                389                EXIT FROM FREE_Q_SEARCH
                                390               FI
                                391               ! GET NEXT MSG !
016F A156                       392               LD     R6, R5
0170 6165  00A2'                393               LD     R5, VPT.MSG_Q.NEXT_MSG(R6)
0174 E8F6                       394              OD
                                395
                                396             ! INSERT IN LIST !
0176 6F63  00A2'                397              LD     VPT.MSG_Q.NEXT_MSG(R6), R3
017A 6F35  00A2'                398              LD     VPT.MSG_Q.NEXT_MSG(R3), R5
                                399             FI
                                400             ! GET MESSAGE INFORMATION:
                                401               (RETURNS R1: SENDING_VP)  !
017E 6131  00A0'                402             LD      R1, VPT.MSG_Q.SENDER(R3)
0182 763A  0090'                403             LDA     R10,VPT.MSG_Q.MSG(R3)
0186 2107  0010                 404             LD      R7,#SIZEOF MESSAGE
018A BAA1  0780                 405             LDIRB   @R8,@R10,R7
018F 9F08                       406             RET
0190                            407           END GET_FIRST_MSG
                                408 !PAGE
```

```
                                409              MAKE_READY  PROCEDURE
                                410                   !*********************************!
                                411                   ! INSERTS SCHEDULE VP ID INTO    !
                                412                   ! READY LIST IAW PRIORITY AND    !
                                413                   ! PUTS IT IN READY STATE.        !
                                414                   !*********************************!
                                415                   ! REGISTER USE:                  !
                                416                   !  PARAMETERS:                  !
                                417                   !     R1: SIGNALED_VP (INPUT)   !
                                418                   !   LOCAL VARIABLES             !
                                419                   !     R2: SIG_VP.PRI            !
                                420                   !     R3: PRESENT_VP            !
                                421                   !     R4: NEXT_VP               !
                                422                   !*********************************!
                                423              ENTRY
0190 6104  0002'                424                LD        R4, VPT.RUNNING_LIST
                                425                          ! * * * DEBUG * * * !
0194 0F04  FFFF                 426                          CP        R4, #NIL
0198 5E0E  01A8'                427                          IF EQ  ! LIST IS EMPTY !  THEN
019C 2100  0003                 428                           LD  R0, #READY_LIST_EMPTY
01A0 7601  01A0'                429                           LDA R1, $
01A4 5F00  A900                 430                           CALL MONITOR
                                431                          FI
                                432                          ! * * END DEBUG * * !
                                433
01A8 6112  0012'                434                LD        R2, VPT.VP.PRI (R1)
                                435
01AC 4842  2012'                436                CP        R2, VPT.VP.PRI(R4)
01B0 5E02  01C0'                437                IF GT  ! SIG_VP.PRI > READY_VP.PRI !  THEN
                                438                 ! INSERT AT FRONT OF LIST !
01B4 6F14  001C'                439                 LD        VPT.VP.NEXT_READY_VP(R1), R4
01B8 6F01  0004'                440                 LD        VPT.READY_LIST, R1
                                441 !PAGE
```

```
                !
01BC 5E08  01E8'     442                ELSE  ! INSERT IN LIST !
                     443
                     444                 READY_LIST_SEARCH:
                     445                  DO  ! WHILE NOT END OF LIST !
01C0 0B04  FFFF      446                   CP     R4, #NIL
01C4 5E0E  01CC'     447                   IF EQ  ! IF END OF LIST  !  THEN
01C8 5E08  01E0'     448                    EXIT FROM READY_LIST_SEARCH
                     449                   FI
                     450
01CC 4B42  0012'     451                   CP     R2, VPT.VP.PRI (R4)
01D0 5F02  01D8'     452                   IF  GT ! SIG_VP.PRI > PRESENT_VP.PRI ! THEN
01D4 5E08  01E0'     453                    EXIT FROM READY_LIST_SEARCH
                     454                   FI
                     455
                     456                   ! GET NEXT LINK !
01D8 A143            457                   LD     R3,R4
01DA 6134  001C'     458                   LD     R4, VPT.VP.NEXT_READY_VP(R3)
01DE E8F0            459                CD
                     460                !   INSERT SIG_VP IN LIST !
01E0 6F14  001C'     461                LD        VPT.VP.NEXT_READY_VP(R1),  R4
01E4 6F31  001C'     462                LD        VPT.VP.NEXT_READY_VP(R3), R1
                     463
                     464                FI
                     465
                     466                ! CHANGE STATE TO READY !
01E8 4D15  0014'     467                LD        VPT.VP.STATE(R1), #READY
01EC 0021
                     468
01EF 9E0E            469                 RET
01F0                 470               END MAKE_READY
                     471 !PAGE
```

```
                                    !
                          472       !  * * INNER TRAFFIC CONTROL ENTRY POINTS * * !
                          473       GLOBAL
                          474       $SECTION ITC_GLB_PROC
                          475
                          476       EARLWARE_PREEMPT LABEL
                          477
0000                      478       WAIT        PROCEDURE
                          479           !*************************************!
                          480           ! INTRA_KERNEL SYNC/COM PRIMITIVE    !
                          481           ! INVOKED BY KERNEL PROCESSES        !
                          482           !*************************************!
                          483           ! PARAMETERS                         !
                          484           !  R8(R9): MSG POINTER (INPUT)      !
                          485           !  R1: SENDING_VP (RETURN)          !
                          486           ! GLOBAL VARIABLES                   !
                          487           !  R14: DFR (PARAM TC GETWORK)      !
                          488           ! LOCAL VARIABLES                    !
                          489           !  R2: CURRENT_VP (RUNNING)         !
                          490           !  R3: NEXT_READY_VP                !
                          491           !  R4: LOCK_ADDRESS                 !
                          492           !*************************************!
                          493        ENTRY
                          494       ! LOCK VPT !
0000 7E04  0000'          495         LDA       R4, VPT.LOCK
0004 5F00  0154'          496         CALL      SPIN_LOCK  ! (R4:^VPT.LOCK) !
                          497       ! NOTE: RETURNS WHEN VPT IS LOCKED BY THIS VP !
                          498
0008 6102  0002'          499         LD        R2, VPT.RUNNING_LIST
000C 6123  001C'          500         LD        R3, VPT.VP.NEXT_READY_VP(R2)
                          501
0010 4D21  001E'          502         CP        VPT.VP.MSG_LIST(R2), #NIL
0014 FFFF
0016 5E0E  004A'          503         IF EQ ! CURRENT VP'S MSG LIST IS EMPTY ! THEN
                          504           ! REMOVE CURRENT_VP FROM READY_LIST !
                          505 !PAGE
```

```
!
                    506                 ! * * * * DEBUG * * * * !
001A 0B03  FFFF     507                 CP      R3, #NIL
001E 5E0E  002E'    508                 IF EQ  THEN
0022 2100  0003     509                  LD  R0, #READY_LIST_EMPTY
0026 7601  0026'    510                  LDA R1, $
002A 5F00  A900     511                  CALL MONITOR
                    512                 FI
                    513                 ! * * * END DEBUG * * * !
                    514
002E 6F03  0004'    515         LD      VPT.READY_LIST, R3
0032 4D25  001C'    516         LD      VPT.VP.NEXT_READY_VP(R2), #NIL
0036 FFFF
                    517
                    518         ! PUT IT IN WAITING STATE !
0038 4D25  0014'    519         LD VPT.VP.STATE(R2), #WAITING
003C 0002
                    520
                    521         ! SET DBR !
003E 612E  0010'    522         LD      R14, VPT.VP.DBR(R2)
                    523         ! SCHEDULE FIRST ELGIBLE READY VP !
0042 93F8           524         PUSH       @R15,R8  !SAVE MSG POINTER!
0044 5F00  0000'    525         CALL GETWORK  !(R14: DBR) !
0048 97F8           526         POP        R8,@R15
                    527       FI
                    528     ! GET FIRST MSG ON CURRENT VP'S MSG LIST !
004A 5F00  0124'    529       CALL GET_FIRST_MSG !COPIES MSG IN MSG ARRAY!
                    530                          !RETURNS  R1:SENDER_VP !
                    531
                    532     ! UNLOCK VPT !
004E 4D08  0000'    533       CLR  VPT.LOCK
                    534
                    535       ! RETURN: R1:SENDER_VP !
0052 9E28           536       RET
0054                537     END WAIT
                    538
                    539 !PAGE
```

```
!
0054                      SIGNAL      PROCEDURE
                               !*********************************!
                               ! INTRA_KERNFL SYNC /COM PRIMATIVE !
                               ! INVOKED BY KERNEL PROCESSES      !
                               !*********************************!
                               ! REGISTER USE:                    !
                               !  PARAMETERS:                     !
                               !   R8(R9): MSG POINTER (INPUT)    !
                               !   R1: SIGNALED VP_ID (INPUT)     !
                               ! GLOBAL VARIABLES                 !
                               !  R14: DBR (PARAM TO GETWORK)     !
                               !  LOCAL VARIABLES:                !
                               !   R1: SIGNALED VP                !
                               !   R2: CURRENT_VP                 !
                               !   R4: VPT.LOCK ADDRESS           !
                               !*********************************!
                          ENTRY
                            ! LOCK VPT !
0054 7604  0000'            LDA       R4, VPT.LOCK
0058 5F00  0154'            CALL      SPIN_LOCK  ! (R4:^VPT.LOCK) !
                          ! NOTE: RETURNS WHEN VPT IS LOCKED BY THIS VP. !
                            ! PLACE MSG IN SIGNALED_VP'S MSG_LIST !
005C 5F00  00BE'            CALL ENTER_MSG_LIST !(R8:MSG PTR,
                                      R1:SIGNALED VP)!

0060 4D11  0014'            CP        VPT.VP.STATE(R1), #WAITING
0064 0002
0066 5E0E  0080'            IF EQ  ! SIGNALED_VP IS WAITING !  THEN

                             ! WAKE IT UP AND MAKE IT READY !
006A 5F00  0190'             CALL MAKE_READY  ! (R1: SIGNALED_VP)) !

                             ! PUT CURRENT_VP IN READY_STATE !
006E 6102  0002'             LD       R2, VPT.RUNNING_LIST
0072 4D25  0014'             LD       VPT.VP.STATE(R2), #READY
0076 0001
                 !PAGE
```

```
!
                        575                 ! SET DPR !
007E 612E  0010'        576                 LD      R14, VPT.VP.DBR(R2)
                        577
                        578               ! SCHEDULE FIRST ELGIBLE READY VP !
007C 5F20  0000'        579                 CALL GETWORK  !(R14: DPR) !
                        580               FI
                        581
                        582               ! UNLOCK VPT !
0080 4D08  0000'        583               CLR  VPT.LOCK
                        584
0084 9E08               585               RET
0086                    586             END SIGNAL
                        587 !PAGE
```

```
!
ØØ86                      SET_PREEMPT          PROCEDURE
                                     !*************************!
                                     ! SETS PREEMPT INTERRUPT ON!
                                     ! TARGET_VP. CALLED BY TC_ !
                                     ! ADVANCE.                 !
                                     !*************************!
                                     ! REGISTER USE:            !
                                     ! PARAMETERS:              !
                                     !  R1:TARGET_VP_ID (INPUT) !
                                     ! LOCAL VARIABLES          !
                                     !  R1: VP_INDEX            !
                                     !*************************!
                          ENTRY
                            ! NOTE: DESIGNED AS SAFE SEQUENCE SO VPT NEED
                              NOT BE LOCKED. !

                            ! CONVERT VP_ID TO VP_INDEX !
ØØ86 BDØØ                   LDK        RØ, #Ø
ØØ88 19ØØ  ØØ2Ø             MULT       RRØ, #SIZEOF VP_TABLE
                              ! THIS LEAVES VP INDEX IN R1 !

                            ! TURN ON TGT_VP PREEMPT FLAG !
ØØ8C 4D15  ØØ18'            LD         VPT.VP.PREEMPT(R1), #ON
ØØ9Ø FFFF

                            ! ** IF TARGET VP NOT LOCAL
                                 ( NOT BOUND TO THIS CPU )
                            [IE,IF <<CPU_SEG>>CPU_ID<>VPT.VP.PHYS_CPU(R1)]
                            THEN SEND HARDWARE PREEMPT INTERRUPT TO
                              VPT.VP.CPU(R1). ** !

ØØ92 9EØ8                   RET
ØØ94                      END SET_PREEMPT
                !PAGE
```

```
                !
0094                    621             IDLE    PROCEDURE
                        622                 !************************!
                        623                 ! LOADS IDLE DBR ON      !
                        624                 ! CURRENT VP. CALLED BY  !
                        625                 ! TC_GETWORK.            !
                        626                 !************************!
                        627                 ! REGISTER USE           !
                        628                 !  GLOBAL VARIABLE      !
                        629                 !   R14: DBR            !
                        630                 !  LOCAL VARIABLES:     !
                        631                 !   R2: CURRENT_VP      !
                        632                 !   R3: TEMP VAR        !
                        633                 !   R4: VPT.LOCK ADDR   !
                        634                 !   R5: TEMP            !
                        635                 !************************!
                        636             ENTRY
                        637               ! LOCK VPT !
0094 7604  0000'        638               LDA       R4, VPT.LOCK
0098 5F00  0154'        639               CALL      SPIN_LOCK  ! (R4:^VPT.LOCK) !
                        640              ! NOTE: RETURNS WHEN VPT IS LOCKED BY THIS VP!
                        641
                        642               ! GET CURRENT VP !
009C 6102  0002'        643               LD        R2, VPT.RUNNING_LIST
                        644
                        645               ! SET DBR !
00A0 612E  0010'        646               LD        R14, VPT.VP.DBR(R2)
                        647
                        648               ! LOAD IDLE DBR ON CURRENT VP !
00A4 2103  0060         649               LD        R3, #IDLE_VP*SIZEOF VP_TABLE
00A8 6135  0010'        650               LD        R5, VPT.VP.DBR(R3)
00AC 6F25  0010'        651               LD        VPT.VP.DBR(R2), R5
                        652
                        653               ! TURN ON CURRENT VP'S IDLE FLAG !
00B0 4D25  0016'        654               LD        VPT.VP.IDLE_FLAG(R2), #ON
00B4 FFFF
                        655 !PAGE
```

```
!
                        656                 ! SET VP TO READY STATE !
00B6 4D25  0014'        657                 LD        VPT.VP.STATE(R2), #READY
00BA 0001
                        658
                        659                 ! SCHEDULE FIRST ELIGIBLE READY VP !
00BC 5F00  0000'        660                 CALL GETWORK  !(R14: DBR) !
                        661
                        662                 ! UNLOCK VPT !
00C0 4D08  0000'        663                 CLR  VPT.LOCK
                        664
00C4 9E08               665                 RET
00C6                    666               END IDLE
                        667 !PAGE
```

```
                                668             SWAP_VDBR   PROCEDURE
                                669                 !************************!
                                670                 ! LOADS NEW DBR ON      !
                                671                 ! CURRENT VP. CALLED BY !
                                672                 ! TC_GETWORK.           !
                                673                 !************************!
                                674                 ! REGISTER USE          !
                                675                 !  PARAMETERS          !
                                676                 !   R1: NEW_DBR (INPUT) !
                                677                 !  GLOBAL VARIABLES    !
                                678                 !   R14: DBR           !
                                679                 !  LOCAL VARIABLES     !
                                680                 !   R2: CURRENT_VP     !
                                681                 !   R4: VPT.LOCK_ADDR  !
                                682                 !************************!
                                683             ENTRY
                                684               ! LOCK VPT !
00C6 7604  0000'                685               LDA       R4, VPT.LOCK
00CA 5F00  0154'                686               CALL      SPIN_LOCK  ! (R4:^VPT.LOCK) !
                                687             ! NOTE: RETURNS WHEN VPT IS LOCKED BY THIS VP.!
                                688               ! GET CURRENT VP !
00CE 6102  0002'                689               LD        R2, VPT.RUNNING_LIST
                                690                         ! * * * DEBUG * * * !
00D2 4D21  001E'                691                         CP VPT.VP.MSG_LIST(R2), #NIL
00D6 FFFF
00D8 5F06  00EE'                692                         IF NE ! MSG WAITING !  THEN
00DC 2100  0005                 693                          LD  R0, #SWAP_NOT_ALLOWED
00E0 7601  00E0'                694                          LDA R1, $   !PC!
00F4 5F00  A900                 695                          CALL MONITOR
                                696                         FI
                                697                         ! * * END DEBUG * * !
                                698               ! SET DBR !
00E8 612E  0010'                699               LD        R14, VPT.VP.DBR(R2)
                                700
                                701 !PAGE
```

AD-A094 569 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 9/2
IMPLEMENTATION OF SEGMENT MANAGEMENT FOR A SECURE ARCHIVAL STOR--ETC(U)
SEP 80 J T WELLS

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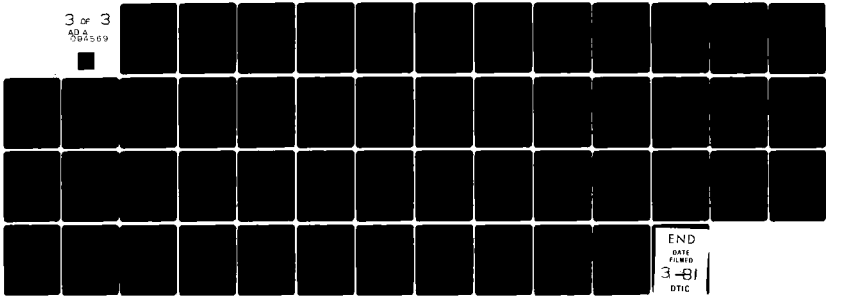

```
!
                                ! LOAD NEW DBR ON CURRENT VP !
00EC 6F21  0010'                LD        VPT.VP.DBR(R2), R1

                                ! TURN OFF IDLE FLAG !
00F0 4D25  0016'                LD        VPT.VP.IDLE_FLAG(R2), #OFF
00F4 0002

                                ! SET VP TO READY STATE !
00F6 4D25  0014'                LD        VPT.VP.STATE(R2), #READY
00FA 0001

                                ! SCHEDULE FIRST ELGIBLE READY VP !
00FC 5F00  0000'                CALL GETWORK  ! (R14:DBR) !

                                ! UNLOCK VPT !
0100 4D08  0000'                CLR  VPT.LOCK

0104 9E08                       RET
0106                          END SWAP_VDBR
           !PAGE
```

```
!
0106                    720             TEST_PREEMPT        PROCEDURE
                        721                         !*********************************!
                        722                         ! TESTS FOR PREEMPT INTERRUPT    !
                        723                         ! FLAG AND HANDLES INTERRUPT     !
                        724                         ! IF FLAG IS SET.                !
                        725                         ! INVOKED UPON EVERY EXIT FROM   !
                        726                         ! KERNEL.                        !
                        727                         !*********************************!
                        728                         ! REGISTER USE                   !
                        729                         !  LOCAL VARIABLES              !
                        730                         !   R1: PREEMPT_INT_FLAG        !
                        731.                        !   R2: CURRENT_VP              !
                        732                         !*********************************!
                        733             ENTRY
                        734               TEST_FLAG:
                        735               DO  ! WHILE CURRENT_VP'S PREEMPT FLAG IS ON !
                        736
                        737             !NOTE: NEXT TWO STATEMENTS MAY NOT BE RACE FREE.
                        738             LOCK MAY BE REQUIRED FOR MULTIPROCESSOR SYS!
                        739
                        740                 ! GET CURRENT VP !
0106 6102  0002'        741                 LD R2, VPT.RUNNING_LIST
                        742
                        743                 ! TEST PREEMPT INTERRUPT FLAG !
010A 6121  0018'        744:                 LD     R1, VPT.VP.PREEMPT(R2)
010E 0FC1  0000         745                 CP R1, #0FF
0112 5E0E  011A'        746;                IF EQ  !  PREEMPT FLAG IS OFF !  THEN
0116 5E08  012C'        747                  EXIT FROM TEST_FLAG
                        748                 FI
                        749
                        750               ! *** VIRTUAL PREEMPT HANDLER *** !
                        751                 !** NOTE: SAFE SEQUENCE AND DOES NOT REQUIRE
                        752                           VPT TO BE LOCKED. ** !
                        753 !PAGE
```

```
!
                        754                     ! RESET PREEMPT FLAG !
011A 4D25  2018'        755                       LD    VPT.VP.PREEMPT(R2), #OFF
011E 0000
                        756
                        757                       ! SIMULATE PREEMPT INTERRUPT !
0120 5F00  0000*        758                       CALL TC_PREEMPT_HANDLER
                        759                   !NOTE: THIS JUMP TO TRAFFIC_CONTROL
                        760                    IS USED ONLY IN THE CASE OF A PREEMPT INTERRUPT
                        761                     AND SIMULATES A HARDWARE INTERRUPT. ** !
                        762
                        763                       ! *** END VIRTUAL PREEMPT HANDLER *** !
0124 E8F0               764                     OD
                        765
                        766                     ! RETURN TC GATEKEEPER !
0126 9E08               767                     RET
                        768
0128                    769                   END TEST_PREEMPT
                        770 !PAGE
```

```
!
0128                          RUNNING_VP  PROCEDURE
                                  !*******************************!
                                  ! CALLED PY TRAFFIC CONTROL.    !
                                  ! RETURNS VP_ID. RESULT IS VALID!
                                  ! CNLY WHILE APT IS LOCKED.     !
                                  !*******************************!
                                  ! REGISTER USE                  !
                                  !  PARAMETERS                   !
                                  !   R1: VP_IL  (RETURNED)       !
                                  !  LOCAL VARIABLES              !
                                  !   RRØ: DIVIDEND               !
                                  !    RØ: REMAINDER              !
                                  !    R1: QUOTIENT               !
                                  !*******************************!
                              ENTRY
                                ! LOCK VPT !
0128 7604  0000'                LDA       R4, VPT.LOCK
012C 5F00  0154'                CALL      SPIN_LOCK  ! (R4:^VPT.LOCK) !
                               ! NOTE: RETURNS WHEN VPT IS LOCKED BY THIS VP !
0130 6101  0002'                LD        R1, VPT.RUNNING_LIST
0134 BD00                       LDK       RØ, #Ø
                                ! CONVERT VP_INDEX TO VP_ID !
0136 1B00  0020                 DIV       RRØ, #SIZEOF VP_TABLE
                                          ! * * * DEBUG * * * !
013A 0B00  0000                           CP  RØ, #Ø
013E 5E06  014E'                          IF NE  !REMAINDER <> Ø !  THEN
0142 2100  0006                            LD RØ, #VP_INDEX_ERROR
0146 7601  0146'                           LDA R1, $
014A 5F00  A900                            CALL MONITOR
                                          FI
                                          ! * * END DEBUG * * !
014E 4D08  0000'                CLR       VPT.LOCK
0152 9E08                       RET
0154                          END RUNNING_VP
                         !PAGE
```

```
!
0154                       SPIN_LOCK   PROCEDURE
                               !**********************!
                               ! USES SPIN_LOCK MECH.  !
                               ! LOCKS UNLOCKED DATA   !
                               ! STRUCTURE (POINTED TO !
                               ! BY INPUT PARAMETER).  !
                               !**********************!
                               !REGISTER USE           !
                               ! PARAMETERS            !
                               !  R4: LOCK ADDR (INPUT)!
                               !**********************!
                           ENTRY
                            !  NOTE: SINCE ONLY ONE PROCESSOR CURRENTLY IN
                                          SYSTEM, LOCK NOT NECESSARY. ** !
                                       ! * * * DEBUG * * * !
0154 0D41  0002                        CP  @R4, #0FF
0158 5E06  0168'                       IF NE ! NOT UNLOCKED !  THEN
015C 2100  0000                         LD  R0, #UNALTE_LOCK
0160 7601  0160'                        LDA R1, $
0164 5F00  A900                         CALL MONITOR
                                       FI
                                       ! * * END DEBUG * * !
                             TEST_LOCK:
                              !  DO WHILE STRUCTURE LOCKED !
0168 0D46                    TSET       @R4
016A E5FE                    JR MI, TEST_LOCK
                               ! ** NOTE SEE PLZ/ASM MANUAL
                                        FOR RESTRICTIONS ON
                                        USE OF TSET. ** !
216C 9E08                    RET

016E                       END SPIN_LOCK

                  !PAGE
```

```
                                    !
016F                        840     ITC_GET_CPU_NO                  PROCEDURE
                            841                     !*************************!
                            842                     ! FIND CURRENT CPU_NO    !
                            843                     ! CALLED BY DIST MMGR    !
                            844                     !*************************!
                            845                     ! REGISTER USE           !
                            846                     ! R1: CPU_NO (RETURNED)  !
                            847                     ! R2: VP INDEX (LOCAL)   !
                            848                     !*************************!
                            849
                            850     ENTRY
016E 7C04   0000'           851         LDA     R4,VPT.LOCK
0172 5F00   0154'           852         CALL    SPIN_LOCK           ! R4: ^VPT.LOCK !
0176 6102   0022'           853         LD      R2,VPT.RUNNING_LIST
017A 6121   001A'           854         LD      R1,VPT.VP.PHYS_PROCESSOR(R2)
017F 4D0E   0000'           855         CLR     VPT.LOCK
0182 9E0E                   856         RET
0184                        857     END ITC_GET_CPU_NO
                            858
                            859
                            860 !PAGE
```

```
!
0184                      ITC_GET_SEG_PTR             PROCEDURE
                              !*******************************!
                              ! GETS BASE ADDRESS OF SEGMENT  !
                              ! INDICATED.                    !
                              !*******************************!
                              ! REGISTER USE:                 !
                              !  R0:SEG BASE ADDRESS(RET)     !
                              !  R1:SEG NR (INPUT)            !
                              !  R2:RUNNING_VP (LOCAL)        !
                              !  R3:DBR_VALUE (LOCAL)         !
                              !  R4:VPT.LOCK                  !
                              !*******************************!

                          ENTRY
0184 7604  0000'              LDA     R4,VPT.LOCK
0188 5F00  0154'              CALL    SPIN_LOCK  !R4:^VPT.LOCK!
018C 6102  0002'              LD      R2,VPT.RUNNING_LIST
0190 6123  0010'              LD      R3,VPT.VP.DBR(R2)
0194 4D08  0000'              CLR     VPT.LOCK
0198 1900  0004               MULT    RR0,#4
019C 7130  0100               LD      R0,R3(R1) !NOTE: DBR (NOT DBR_NO)
                                                      USED HERE!
01A0 9E08                     RET
01A2                      END ITC_GET_SEG PTR
                !PAGE
```

```
                                    !
01A2                        886     K_LOCK                  PROCEDURE
                            887             !*********************!
                            888             ! STUB FOR WAIT LOCK!
                            889             !*********************!
                            890             ! R4: ^LOCK (INPUT) !
                            891             !*********************!
                            892
                            893     ENTRY
01A2 5F00  0154'            894         CALL SPIN_LOCK
01A6 9F08                   895         RET
01AE                        896     END K_LOCK
                            897
                            898
01A8                        899     K_UNLCCK                PROCEDURE
                            900         !************************!
                            901         ! STUB FOR WAIT UNLOCK  !
                            902         !************************!
                            903         ! R4: ^LOCK (INPUT)     !
                            904         !************************!
                            905
                            906     ENTRY
01AE 0140                   907         CLR     @R4
01AA 9E0E                   908         RET
01AC                        909     END K_UNLOCK
                            910
                            911     END INNER_TRAFFIC_CONTROL
                            912 !PAGE
```

```
!
                TC MODULE

                      ! 11 SEP 1980 !

                 CONSTANT
                 ! ************ DEBUG CODES ************ !
                              BLOCKED_LIST_ERROR      := 4
                              READY_LIST_ERROR        := 1
                              RUNNING_LIST_ERROR      := 2

                 ! ******** SYSTEM PARAMETERS ******** !
                              NR_PROCESSES    :=4
                              NR_MMU_REG      :=64
                              NR_VP           :=4
                              NR_AVAIL_VP     :=2
                              STACK_SEG       :=1
                              STACK_SEG_SIZE :=%100

                 ! * * OFFSETS (FROM TOP OF STACK) * * !
                     PROCESS_ID      := STACK_SEG_SIZE-%1E

                 ! ******** SYSTEM CONSTANTS ******** !
                    TRUE     := 1
                    FALSE    := 0
                    ON       := %FFFF
                    OFF      := 0
                    RUNNING  := 0
                    READY    := 1
                    BLOCKED  := 2
                    IDIF1    := %DDDD
                    NIL      := %FFFF
                    INVALID  := %EEEE
                    MONITOR  := %A902          ! DEBUG ENTRY !
 !PAGE
```

```
!
                TYPE
                 AP_POINTER  WORD
                 ADDRESS     WORD
                 EVENT_TABLE  RECORD
                    [ HANDLE          WORD
                      EVENT           WORD
                      TICKET          WORD
                      FILLER_2        ARRAY [5 WORD]
                    ]
                 AP_TABLE RECORD
                       [DBR_NO         SHORT INTEGER
                        FILLER_0       BYTE
                       SAC             LONG
                       PRI             INTEGER
                       STATE           INTEGER
                       NEXT_AP         AP_POINTER
                       FILLER_1        ARRAY [2 WORD]
                       EVENTCOUNT      EVENT_TABLE
                      ]

                RUNNING_ARRAY  ARRAY [NR_AVAIL_VP  WORD]
!PAGE
```

```
!

                    EXTERNAL
                        SPIN_LOCK                   PROCEDURE
                        SET_PREEMPT                 PROCEDURE
                        SWAP_VDBR                   PROCEDURE
                        IDLE                        PROCEDURE
                        RUNNING_VP                  PROCEDURE
                        MM_GET_DBR_VALUE            PROCEDURE
                        K_LOCK                      PROCEDURE
                        K_UNLOCK                    PROCEDURE

                    $SECTION TC_DATA
                    INTERNAL
0000                 APT RECORD
                      ( SUCCESS_CODE     WORD
                        LOCK             WORD
                        RUNNING_LIST     RUNNING_ARRAY
                        READY_LIST       WORD
                        BLOCKED_LIST     WORD
                        FILLER           ARRAY(2 WORD)
                        AP               ARRAY (NR_PROCESSES AP_TABLE)
                      )
!PAGE
```

```
!
                      GLCBAL
                      $SECTION TC_GIB_PROC

0000                   TC_GETWORK        PROCEDURE
                                 !***********************!
                                 ! LOADS NEXT READY DBR  !
                                 ! ON CURRENT VP.        !
                                 !***********************!
                                 ! REGISTER USE          !
                                 !  LOCAL VARS           !
                                 !   R1: CURRENT_VP_ID   !
                                 !   R2: READY_AP        !
                                 !   R3: VP_PTR          !
                                 !***********************!
                       ENTRY
                        ! FIND FIRST READY PROCESSOR !
0002 6122  0008'        LD         R2, APT.READY_LIST
                        READY_AP_SEARCH:
                        DC  ! WHILE NOT (END OF LIST OR READY PROCESS) !

0004 0302  FFFF           CP       R2, #NIL
0006 5E0F  0010'          IF EQ  ! IF NO READY PROCESSES !  THEN
000C 5E08  0026'           EXIT FROM READY_AP_SEARCH
                          FI

0010 4D21  0013'          CP       APT.AP.STATE(R2), #REALY
0014 0001
0016 5E0E  001E'          IF EQ  ! IF PROCESS READY !  THEN
001A 5E08  0026'           EXIT FROM READY_AP_SEARCH
                          FI

                          ! GET NEXT READY AP !
001E 6123  001A'          LD       R3, APT.AP.NEXT_AP(R2)
0022 A132                 LD             R2, R3
0024 E8FF               OD
             !PAGE
```

```
!
0026 0E02  FFFF                    CP        R2,#NIL
002A 5E0F  003C'                   IF EQ ! IF NO PROCESSES READY ! THEN
                                    ! LOAD IDLE PROCESS !
002E 4D15  0004'                    LD        APT.RUNNING_LIST(R1), #IDLE1
0032 DDDD
0034 5F00  0000*                    CALL IDLE
0038 5E08  0054'                   ELSE
                                    ! LOAD FIRST READY AP !
003C 6F12  0004'                    LD        APT.RUNNING_LIST(R1), R2
0040 4D25  0018'                    LD        APT.AP.STATE(R2), #RUNNING
0044 0000
0046 6029  0013'                    LDB       RL1, APT.AP.DBR_NO(R2)
004A 5F00  0000*                    CALL      MM_GET_DBR_VALUE  !(R1:DBR_NO)!
                                                                !(RETURNS:R2:IFR)!
004E A121                           LD        R1,R2  !DBR VALUE (ADDRESS)!
0050 5F00  0000*                    CALL SWAP_VDBR  !(R1:DBR)!
                                   FI
0054 9E08                          RET
0056                             END TC_GETWORK
         !PAGE
```

```
                                !
0056                        133             TC_PREEMPT_HANLLER      PROCEDURE
                            134                     !*************************!
                            135                     ! LOADS FIRST READY AP   !
                            136                     ! IN RESPONSE TO PREEMPT  !
                            137                     ! INTERRUPT              !
                            138                     !*************************!
                            139                     ! GLOBAL (TC) VARIABLES  !
                            140                     !  R12: CURRENT PROCESS  !
                            141                     !  R13: SEG BASE ADDR    !
                            142                     !  R14: DER NO           !
                            143                     !*************************!
                            144             ENTRY
                            145                 !** CALL WAIT_LOCK (APT^.LOCK) **!
                            146                 !** RETURNS WHEN PROCESS HAS LOCKED APT **!
                            147               ! GET RUNNING VP ID !
0056 5F00  0000*            148               CALL RUNNING_VP !(RETURNS: R1:VP_ID)!
                            149
                            150               ! GET AP !
005A 6112  0004'            151               LD        R2, APT.RUNNING_LIST(R1)
                            152
                            153               ! IF NOT AN IDLE PROCESS, SET IT TO READY !
005F 0F02  DDDD             154               CP        R2, #IDLE1
0062 5E26  006C'            155               IF NE ! NOT IDLE !  THEN
0066 4D25  0018'            156                LD       APT.AP.STATE(R2), #READY
006A 0001
                            157               FI
                            158
                            159               ! LOAD FIRST READY PROCESS !
006C 5F00  0020'            160               CALL TC_GETWORK
                            161                 !** CALL WAIT_UNLOCK (APT^.LOCK) **!
                            62                 !** RETURNS WHEN PROCESS HAS UNLOCKED APT **!
                            163                 !** AND ADVANCED ON THIS EVENT **!
0070 9E08                   164               RET
0072                        165             ENL TC_PREEMPT_HANDLER
                            166 !PAGE
```

```
                                    !
0072                        167     TC_GET_PROC_CLASS          PROCEDURE
                            168                 !**********************!
                            169                 ! SEARCHES APT FOR     !
                            170                 ! CURRENT PROC CLASS   !
                            171                 ! CALLED BY SFG MGR    !
                            172                 !**********************!
                            173                 ! REGISTER USE         !
                            174                 ! PARAMETERS           !
                            175                 ! R1:CUR_VP_ID(LOCAL)  !
                            176                 ! RR2:SAC(RETURNED)    !
                            177                 ! R5:PROCESS_ID(LOCAL) !
                            178                 !**********************!
                            179
                            180     ENTRY
0272 7604  0002'            181         LDA         R4,APT.LOCK
0074 5F00  0000*            182         CALL K_LOCK                 !(R4:APT.LOCK)!
007A 5F00  0000*            183         CALL RUNNING_VP             ! (RETURNS R1:VP_ID) !
007E 6115  0004'            184         LD          R5,APT.RUNNING_LIST(R1)
0082 5452  0012'            185         LDL         RR2,APT.AP.SAC(R5)
0086 4D08  0002'            186         CLR         APT.LOCK
008A 9E08                   187         RET
008C                        188     END TC_GET_PROC_CLASS
                            189 !PAGE
```

```
                    !
008C                190             TC_GET_DBR_NO                   PROCEDURE
                    191                 !*********************************!
                    192                 ! SEARCHES APT FOR CURRENT VALUE!
                    193                 ! OF DBR_NO.                     !
                    194                 !*********************************!
                    195                 ! REGISTER USE:                  !
                    196                 !  R1:CUR_VP_ID (LOCAL)         !
                    197                 !  R1:DBR_NO (RETURNED)         !
                    198                 !  R4:APT.LOCK (LOCAL)          !
                    199                 !  R5:PROCESS_ID (LOCAL)        !
                    200                 !*********************************!
                    201
                    202             ENTRY
0088 7604  0002'    203                 LDA     R4,APT.LOCK
008C 5F00  0000*    204                 CALL    K_LOCK  !R4:^APT.LOCK!
0090 5F00  0000*    205                 CALL    RUNNING_VP  ! (RETURNS:R1:VP_ID) !
0094 6115  0004'    206                 LD      R5,APT.RUNNING_LIST(R1)
0098 6059  0010'    207                 LDB     RL1,APT.AP.DBR_NO(R5)
009C 4D08  0002'    208                 CLR     APT.LOCK
00A0 9F08           209                 RET
00A2                210             END TC_GET_DBR_NO
                    211
                    212             END TC
                    213
                    214 !PAGE
```

```
                                    !
                                     2 IDLE_PROCESS MODULE
                                     3   ! VERS. 1.8 !
                                     4  CONSTANT
                                     5   WRITELN        := %0FC0          !PUTMSG MONITOR CALL !
                                     6   RETURN_TO_EPUG := %A902
                                     7
                                     8 EXTERNAL
                                     9   SIGNAL           PROCEDURE
                                    10   WAIT             PROCEDURE
                                    11   IDLE             PROCEDURE
                                    12   SET_PREEMPT      PROCEDURE
                                    13   SWAP_VDBR        PROCEDURE
                                    14   TEST_PREEMPT     PROCEDURE
                                    15
                                    16 INTERNAL
                                    17
                                    18 $SECTION IDLE_DATA
0000 49 20 2A                       19 MSG ARRAY [* BYTE]:='I ** IDLE PROCESS IS RUNNING! ** %R'
0003 2A 20 49
0006 44 4C 45
0009 20 50 52
000C 4F 43 45
000F 53 53 20
0012 49 53 20
0015 52 55 4E
0018 4E 49 4E
001B 47 21 20
001E 2A 2A 20
0021 0D
                                    20 !PAGE
```

```
!
0000                  $SECTION IDLE_PROC
                            IDLE_MAIN  PROCEDURE

                            ENTRY
0000 2102  0000'               LD       R2, #MSG
0024 5F00  0FC0                CALL     WRITELN
0008 5F00  A902                CALL     RETURN_TO_HBUG
000C 9E08                      RET

                            TEST_ENTRY:
                               ! PARAMETER R10: CALLS PROCEDURES !
                               IF  R10
000E 0B0A  0000                         CASE #0 THEN CALL IDLE
0012 5E0E  001F'
0016 5F00  0000*
001A 5E08  0052'                        CASE #1 THEN CALL SWAP_VDER
001F 0B0A  0001
0022 5E0F  002E'
0026 5F00  0000*
002A 5E08  0052'                        CASE #2 THEN CALL SET_PREEMPT
002E 0B0A  0002
0032 5E0E  003E'
0036 5F00  0000*
003A 5E08  0052'                        CASE #3 THEN CALL TEST_PREEMPT
003E 0B0A  0003
0042 5F0E  004E'
0046 5F00  0000*
004A 5E08  0052'               ELSE
004E 5F00  A902                 CALL RETURN_TO_HBUG

                               FI

0052 9E08                      RET
0054                        END IDLE_MAIN

                      END IDLE_PROCESS
                      !PAGE
```

```
!
 2 MM_PROCESS       MODULE
 3
 4 ! VERS. 1.8      !
 5
 6  CONSTANT
 7   WRITE           := %0FC8          ! TYWR MON CALL !
 8   WRITFLN         := %0FC0          ! PUTMSG MON CALL !
 9   CRLF            := %0FD4          ! MON CALL        !
10   RETURN_TO_MONITOR  := %A902       ! HBUG REENTRY     !
11
12   COUNT := 10
13   TIME  := 500
14
15   SPACE := %20
16   DASH  := %2D
17
18   IO_MGR          := %20
19   FILE_MGR        := %40
20   MEM_MGR         := %60
21   CREATE_ENTRY_CODE  := 50
22   INVALID_MMGR_CODE  := 60
23   DELETE_ENTRY_CODE  := 51
24   ACTIVATE_SEG_CODE  := 52
25   DEACTIVATE_SEG_CODE:= 53
26   SWAP_IN_SEG_CODE   := 54
27   SWAP_OUT_SEG_CODE  := 55
28   SUCCEEDED          := 2
29
30 !PAGE
```

```
                    !
                    31    TYPE
                    32    ADDRESS                   WORD
                    33    SEG_DESC_REG     RECORD [BASE_ADDR  ADDRESS
                    34                             LIMIT      BYTE
                    35                             ATTRIBUTE  BYTE]
                    36      MMU            RECORD  [SDR  ARRAY  [64  SEG_DESC_REG]]
                    37                              !BLKS_USED     WORD
                    38                              MAX_BLKS       WORD]!
                    39                             !NOTE: LAST TWO MMU COMPONENTS LEFT
                    40                             OFF FOR CONVENIENCE SINCE ARE NOT
                    41                             USED FOR THE SEG MGR DEMO!
                    42  EXTERNAL
                    43    SIGNAL             PROCEDURE
                    44    WAIT               PROCEDURE
                    45
                    46   GLOBAL
                    47   $SECTION MMU_DATA
211 0000            48          MMU_IMAGE                  ARRAY [4   MMU]
                    49   $SECTION MM_DATA
    0000 0000       50          G_AST_LOCK                 WORD  := 0
                    51
                    52  !PAGE
```

```
!
                                53  INTERNAL
                                54
                                55   ! * * * * MESSAGES * * * * !
0002 08  28  46                 56    IO            ARRAY [* BYTE] := '%08(FOR IO)'
0005 4F  52  20
0008 49  4F  29
000B 08  28  46                 57    FM            ARRAY [* BYTE] := '%08(FOR FM)'
000E 4F  52  20
0011 46  4D  29
0014 12  4B  45                 58    MM_MSG_1      ARRAY [* BYTE] := '%12KERNEL = SIGNALLER'
0017 52  4E  45
001A 4C  20  3D
001D 20  53  49
0020 47  4E  41
0023 4C  4C  45
0026 52
0027 10  4D  4D                 59    CREATE_MSG    ARRAY [* BYTE] := '%10MM: CREATE_ENTRY'
002A 3A  20  43
002D 52  45  41
0030 54  45  5F
0033 45  4E  54
0036 52  59
0038 10  4D  4D                 60    DELETE_MSG    ARRAY [* BYTE] := '%10MM: DELETE_ENTRY'
003B 3A  20  44
003E 45  4C  45
0041 54  45  5F
0044 45  4E  54
0047 52  59
                                61 !PAGE
```

```
!
0049 0C  4D  4D       62    ACTIVATE_MSG ARRAY [* BYTE] := '%0CMM: ACTIVATE'
004C 3A  20  41
004F 43  54  49
0052 56  41  54
0055 45
0056 0E  4D  4D       63    DEACTIVATE_MSG  ARRAY [* BYTE] := '%0EMM: DEACTIVATE'
0059 3A  20  44
005C 45  41  43
005F 54  49  56
0062 41  54  45
0065 0B  4D  4D       64    SWAP_IN_MSG  ARRAY [* BYTE] := '%0BMM: SWAP_IN'
0068 3A  20  53
006B 57  41  50
006E 5F  49  4E
0071 0C  4D  4D       65    SWAP_OUT_MSG ARRAY [* BYTE] := '%0CMM: SWAP_OUT'
0074 3A  20  53
0077 57  41  50
007A 5F  4F  55
007D 54
007E 0C  49  4E       66    ERROR_MSG ARRAY [* BYTE] := '%0CINVALID CODE'
0081 56  41  4C
0084 49  44  20
0087 43  4F  44
008A 45
008B 02  00  00       67    RET_VALUES ARRAY[* BYTE]:=[2,0,0,0,0,16,0,17,0,3,0,
008E 00  00  10
0091 00  11  00
0094 03  00  01
0097 00  30  00
009A 00
                      68                                1,0,48,0,0]
0098                  69    MM_MSG_ARRAY  ARRAY [16  BYTE]
00AC                  70    SENDER          WORD
                      71 !PAGE
```

```
!
                        72 INTERNAL
                        73
                        74 $SECTION MM_PROC
                        75
0000                    76   MM_MAIN PROCEDURE
                        77               ENTRY
                        78               DO !** DO FOREVER **!
0000 760E  009F'        79                   LDA     R6,MM_MSG_ARRAY[0]
0004 5F00  0000*        80                   CALL    WAIT
0008 6F01  00AC'        81                   LD      SENDER, R1 !SAVE SIGNALING PROC #!
000C 2103  0032         82                   LD      R3,#50
0010 5F00  0178'        83                   CALL    MM_PRINT_BLANKS
0014 2102  0014'        84                   LD      R2,#MM_MSG_1
0018 5F00  0FC0         85                   CALL    WRITELN
001C 6101  00AC'        86                   LD      R1,SENDER
                        87                   IF      R1
0020 0B01  0020         88                           CASE #IO_MGR THEN LD R2,#IO
0024 5E0E  0334'
0028 2102  0002'
002C 5F00  0FC0         89                                   CALL WRITELN
0030 5F08  0044'        90                           CASE #FILE_MGR THEN LD R2,#FM
0034 0B01  0040
0038 5E0E  0044'
003C 2102  002B'
0040 5F00  0FC0         91                                   CALL WRITELN
                        92                   FI
0044 5F00  0144'        93                   CALL    MM_DELAY
0048 5F00  0FD4         94                   CALL    CRLF
004C 2103  0032         95                   LD      R3,#50
0050 5F00  0178'        96                   CALL    MM_PRINT_BLANKS
0054 6001  009B'        97                   LDB     RH1,MM_MSG_ARRAY[0]
005E 6009  009C'        98                   LDB     RL1,MM_MSG_ARRAY[1]
                        99 !PAGE
```

```
!
                                100
0050 0F01  0032                 101
0060 5E0E  006C'
0064 5F00  00E8'                102
0068 5E08  00C0'                103
006C 0B01  0033
0070 5E0E  007C'
0074 5F00  00F6'                104
0078 5E08  00C0'                105
007C 0B01  0034
0080 5E0E  008C'
0084 5F00  0104'                106
0088 5E08  00C0'                107
008C 0B01  0035
0090 5E0E  009C'
0094 5F00  011A'                108
0098 5F08  00C0'                109
009C 0B01  0036
00A0 5E0E  00AC'
00A4 5F00  0128'                110
00A8 5E08  00C0'                111
00AC 0B01  0037
00B0 5E0F  00BC'
00B4 5F00  0136'                112
00B8 5E08  00C0'                113
00BC 2102  007E'                114
                                115
                                116 !PAGE

IF      R1
        CASE #CREATE_ENTRY_CODE THEN

                CALL    CREATE_ENTRY
        CASE #DELETE_ENTRY_CODE THEN

                CALL  DELETE_ENTRY
        CASE #ACTIVATE_SEG_CODE THEN

                CALL  ACTIVATE
        CASE #DEACTIVATE_SEG_CODE THEN

                CALL  DEACTIVATE
        CASE #SWAP_IN_SEG_CODE THEN

                CALL SWAP_IN
        CASE #SWAP_OUT_SEG_CODE THEN

                CALL SWAP_OUT
ELSE
        LD      R2,#ERROR_MSG
FI
```

```
!
00CC 5F00  0FC0        CALL    WRITELN
00C4 5F00  0144'       CALL    MM_DELAY
00C8 5F00  0FD4        CALL    CRLF
00CC 2103  004B        LD      R3,#75
00D0 5F02  0160'       CALL    MM_PRINT_LINE
00D4 5F00  0FD4        CALL    CRLF
                    ! ** SIGNAL (SENDER, 'DONE') ** !
00DE 6101  00AC'       LD      R1, SENDER
00DC 7608  009B'       LDA     R8,MM_MSG_ARRAY[0]
00E0 5F00  0000*       CALL SIGNAL
00E4 E88D           OD ! ** REPEAT FOREVER ** !
00E6 9E08           RET
00E8                END MM_MAIN


00E8                CREATE_ENTRY                    PROCEDURE

                    ENTRY
00E8 7608  009B'       LDA   R8,MM_MSG_ARRAY[0]
00EC 0C85  0202        LDB   @R8,#SUCCEEDED
00F0 2102  0027'       LD      R2,#CREATE_MSG
00F4 9E08              RET
00F6                END CREATE_ENTRY


00F6                DELETE_ENTRY                    PROCEDURE

                    ENTRY
00F6 7628  009B'       LDA   R8,MM_MSG_ARRAY[0]
00FA 0C85  0202        LDB   @R8,#SUCCEEDED
00FE 2102  0038'       LD    R2,#DELETE_MSG
0102 9E08              RET
0104                END DELETE_ENTRY

      !PAGE
```

```
                !
0104                        152             ACTIVATE                    PROCEDURE
                            153
                            154             ENTRY
0104 7608  009B'            155                 LDA   R8,MM_MSG_ARRAY[0]
0108 7609  00EB'            156                 LDA   R9,RET_VALUES[0]
010C 2102  0010             157                 LD    R2,#16
0110 BA91  0280             158                 LDIRB @R8,@R9,R2
0114 2102  0049'            159                 LD    R2,#ACTIVATE_MSG
0118 9E08                   160                 RET
011A                        161             END ACTIVATE
                            162
                            163
011A                        164             DEACTIVATE                  PROCEDURE
                            165
                            166             ENTRY
011A 7608  009B'            167                 LDA   R8,MM_MSG_ARRAY[0]
011E 0C85  0202             168                 LDB   @R8,#SUCCEEDED
0122 2102  0056'            169                 LD    R2,#DEACTIVATE_MSG
0126 9E08                   170                 RET
0128                        171             END DEACTIVATE
                            172
                            173
0128                        174             SWAP_IN                     PROCEDURE
                            175
                            176             ENTRY
012E 760E  009B'            177                 LDA   R8,MM_MSG_ARRAY[0]
012C 0C85  0202             178                 LDB   @R8,#SUCCEEDED
0130 2102  0065'            179                 LD    R2,#SWAP_IN_MSG
0134 9E0E                   180                 RET
0136                        181             END SWAP_IN
                            182
                            183
                            184 !PAGE
```

```
!
0136                                185             SWAP_OUT                        PROCEDURE
                                    186
                                    187             ENTRY
0136 7608  009B'                    188                 LDA   R8,MM_MSG_ARRAY[0]
013A 0CE5  0202                     189                 LDB   @R8,#SUCCEEDED
013E 2102  0071'                    190                 LD    R2,#SWAP_OUT_MSG
0142 9E08                           191                 RET
0144                                192             END SWAP_OUT
                                    193
                                    194
                                    195
                                    196
0144                                197     MM_DELAY    PROCEDURE
                                    198                 !************************!
                                    199                 ! PRODUCES 2 SEC DELAY !
                                    200                 !************************!
                                    201             ENTRY
0144 2102  000A                     202                 LD      R2, #COUNT
0148 2101  01F4                     203                 LD      R1, #TIME
                                    204                 DO
014C 0B02  0000                     205                  CP     R2, #0
0150 5E0E  0158'                    206                  IF EQ THEN EXIT FI
0154 5E0E  015F'
0158 AB20                           207                  DEC    R2
015A 7B1D                           208                  MREQ   R1
015C FEF7                           209                 OD
015E 9F08                           210                 RET
0160                                211             END MM_DELAY
                                    212
                                    213 !PAGE
```

```
!
                        214
0160                    215    MM_PRINT_LINE          PROCEDURE
                        216                           ! ********************* !
                        217                           ! PRINTS LINE LENGTH   !
                        218                           ! SPEC IN R3.          !
                        219                           ! ********************* !
                        220                ENTRY
0160 C82D               221                    LDB     RL0, #DASH
                        222                    DO
0162 0B03  0000         223                     CP     R3, #0
0166 5E0E  016F'        224                     IF EQ THEN EXIT FI
016A 5E0E  0176'
016E 5F00  0FC8         225                     CALL WRITE
0172 AB30               226                     DEC    R3
0174 E8F6               227                    OD
0176 9E08               228                    RET
0178                    229                END MM_PRINT_LINE
                        230
0178                    231    MM_PRINT_BLANKS        PROCEDURE
                        232                           ! ********************* !
                        233                           ! PRINTS NUMBER OF     !
                        234                           ! BLANKS SPEC IN R3.   !
                        235                           ! ********************* !
                        236                ENTRY
0178 C820               237                    LDB     RL0, #SPACE
                        238                    DO
017A 0B03  0000         239                     CP     R3, #0
017E 5E0E  0186'        240                     IF EQ THEN EXIT FI
0182 5E08  018E'
0186 5F00  0FC8         241                     CALL WRITE
018A AB30               242                     DEC    R3
018C E8F6               243                    OD
018E 9F08               244                    RET
0190                    245                END MM_PRINT_BLANKS
                        246
                        247        END MM_PROCESS
                        248 !PAGE
```

```
!
 2 FM_PROCESS       MODULE
 3
 4 !  VERS  1.8        !
 5  CONSTANT
 6   WRITE            := %ØFC8          ! TYWR MON CALL !
 7   WRITELN          := %ØFCØ          ! PUTMSG MON CALL !
 8   CRLF             := %ØFD4          ! MON CALL         !
 9   RETURN_TO_MONITOR  := %A902        ! HBUG REENTRY      !
10
11   COUNT := 10
12   TIME  := 5ØØ
13
14   SPACE := %2Ø
15   DASH  := %2D
16
17   IO_MGR           := %2Ø
18   FILE_MGR         := %4Ø
19   MEM_MGR          := %ØØ
20
21 EXTERNAL
22   SIGNAL             PROCEDURE
23   WAIT               PROCEDURE
24   CREATE_SEG         PROCEDURE
25   DELETE_SEG         PROCEDURE
26   SM_SWAP_IN         PROCEDURE
27   SM_SWAP_OUT        PROCEDURE
28   TERMINATE          PROCEDURE
29   MAKE_KNOWN         PROCEDURE
30
31 !PAGE
```

```
!
                                        32 $SECTION FM_DATA
                                        33  INTERNAL
                                        34
                                        35   ! * * * * MESSAGES * * * * !
0000 12  46  4D                         36   FM_MSG_1 ARRAY [* BYTE]:='%12FM: IO = SIGNALLER'
0003 3A  20  49
0006 4F  20  3D
0009 20  53  49
000C 47  4E  41
000F 4C  4C  45
0012 52
0013 17  46  4D                         37   FM_MSG_2 ARRAY [* BYTE]:='%17FM: CALL KERNEL(CREATE)'
0016 3A  20  43
0019 41  4C  4C
001C 20  4B  45
001F 52  4E  45
0022 4C  28  43
0025 52  45  41
0028 54  45  29
002B 16  46  4D                         38   FM_MSG_3 ARRAY [* BYTE]:='%16FM: RETURN FROM KERNEL'
002F 3A  20  52
0031 45  54  55
0034 52  4E  20
0037 46  52  4F
003A 4D  20  4B
003D 45  52  4E
0040 45  4C
0042 17  46  4D                         39   FM_MSG_4 ARRAY [* BYTE]:='%17FM: CALL KERNEL(DELETE)'
0045 3A  20  43
0048 41  4C  4C
004B 20  4B  45
004E 52  4E  45
0051 4C  28  44
0054 45  4C  45
0057 54  45  29
                                        40 !PAGE
```

```
!
005A 1E  46  4C      41    FM_MSG_5 ARRAY [* BYTE]:='%1EFM: CALL KERNEL(SWAP_IN)'
005D 3A  20  43
0060 41  4C  4C
0063 20  4B  45
0066 52  4F  45
0069 4C  28  53
006C 57  41  50
006F 5F  49  4E
0072 29
0073 1D  46  4D      42    FM_MSG_6 ARRAY [* BYTE]:='%19FM: CALL KERNEL(SWAP_OUT)'
0076 3A  20  43
0079 41  4C  4C
007C 20  4B  45
007F 52  4E  45
0082 4C  28  53
0085 57  41  50
0088 5F  4F  55
008B 54  29
008D 1A  46  4D      43    FM_MSG_7 ARRAY [* BYTE]:='%1AFM: CALL KERNEL(TERMINATE)'
0090 3A  20  43
0093 41  4C  4C
0096 20  4B  45
0099 52  4E  45
009C 4C  28  54
009F 45  52  4D
00A2 49  4E  41
00A5 54  45  29
00A8 1B  46  4D      44    FM_MSG_8 ARRAY[* BYTE]:='%1BFM: CALL KERNEL(MAKE_KNOWN)'
00AB 3A  20  43
00AE 41  4C  4C
00B1 20  4B  45
00B4 52  4E  45
00B7 4C  28  4D
00BA 41  4B  45
00BD 5F  4B  4E
00C0 4F  57  4E
00C3 29

                     45 !PAGE
```

```
                                  !
00C4                              SENDER   WORD
00C6                              FM_MSG_ARRAY  ARRAY [16  BYTE]
                                  INTERNAL
                                  $SECTION FM_PROC
0000                              FM_MAIN PROCEDURE
                                          ENTRY
                                          DO !** DO FOREVER **!
                                              !FIRST MSG FROM IO PROC (CREATE)!
0000 5F00  0072'                              CALL WAIT_CALL
0004 5F00  0178'                              CALL PRINT_IO_IS_SIGNALLER
0008 5F00  0080'                              CALL  CREATE_CALL
000C 5F00  0138'                              CALL FM_PRINT_RET_FROM_KER
                                              !SIGNAL IO PROC FINISHED!
0010 5F00  0064'                              CALL FM_SIGNAL_CALL
                                              !MSG FROM IO PROC (MK KNOWN & SWAP_IN)!
0014 5F00  0072'                              CALL WAIT_CALL
0018 5F00  0178'                              CALL PRINT_IO_IS_SIGNALLER
001C 5F00  00C8'                              CALL MK_CALL
0020 5F00  0138'                              CALL FM_PRINT_RET_FROM_KER
0024 5F00  0104'                              CALL SWAP_IN_CALL
0028 5F00  0138'                              CALL FM_PRINT_RET_FROM_KER
                                              !SIGNAL IO PROC FINISHED!
002C 5F00  0064'                              CALL FM_SIGNAL_CALL
                                              !MSG FROM IO PROC (SWAP_OUT & TERMINATE)!
0030 5F00  0072'                              CALL WAIT_CALL
0034 5F00  0178'                              CALL PRINT_IO_IS_SIGNALLER
0038 5F00  011E'                              CALL SWAP_OUT_CALL
003C 5F00  0138'                              CALL FM_PRINT_RET_FROM_KER
0040 5F00  00EA'                              CALL TERMINATE_CALL
0044 5F00  0138'                              CALL FM_PRINT_RET_FROM_KER
                                              !SIGNAL IO PROC FINISHED!
0048 5F00  0064'                              CALL FM_SIGNAL_CALL
                                              !NEXT MSG FROM IO PROC (DELETE)!
224C 5F00  0072'                              CALL WAIT_CALL
                                  !PAGE
```

```
!
0050 5F00  0178'        CALL PRINT_IO_IS_SIGNALLER
0054 5F00  00AA'        CALL DELETE_CALL
0058 5F00  0138'        CALL FM_PRINT_RET_FROM_KER
                        !SIGNAL IO PROC FINISHED!
005C 5F00  0064'        CALL FM_SIGNAL_CALL
0060 E8CF           OD !**REPEAT FOREVER**!
0062 9E08           RET
0064                END FM_MAIN



0064                FM_SIGNAL_CALL              PROCEDURE

                    ENTRY
0064 6101  00C4'        LD      R1, SENDER
0068 7608  00C6'        LDA     R8,FM_MSG_ARRAY[0]
006C 5F00  0000*        CALL    SIGNAL
0070 9E08               RET
0072                END FM_SIGNAL_CALL


0072                WAIT_CALL            PROCEDURE

                    ENTRY
0072 7608  00C6'        LDA     R8,FM_MSG_ARRAY[0]
0076 5F00  0000*        CALL    WAIT
007A 6F01  00C4'        LD      SENDER, R1 ! SAVE SIGNALING PROCESS # !
007E 9E08               RET
0080                END WAIT_CALL

           !PAGE
```

```
                                  !
02E0                         112                  CREATE_CALL          PROCEDURE
                             113
                             114                  ENTRY
0080 2103  0019              115                      LD       R3,#25
0084 5F00  01C6'             116                      CALL     FM_PRINT_BLANKS
0088 2102  0013'             117                      LD       R2, #FM_MSG_2
008C 5F00  015E'             118                      CALL     FM_PRINT_MSG
0090 2101  000A              119                      LD       R1,#10    !MENTOR SEG #!
0094 2102  0001              120                      LD       R2,#1     !ENTRY #!
0098 2103  0030              121                      LD       R3,#48    !SIZE!
009C 2104  0003              122                      LD       R4,#3     !UPPER WORD OF CLASS!
00A0 2105  0001              123                      LD       R5,#1     !LOWER WORD OF CLASS!
00A4 5F00  0000*             124                      CALL     CREATE_SEG
00A8 9E08                    125                      RET
02AA                         126                  END CREATE_CALL
                             127
                             128
02AA                         129                  DELETE_CALL          PROCEDURE
                             130
                             131                  ENTRY
00AA 2103  0019              132                      LD       R3,#25
00AE 5F00  01C6'             133                      CALL     FM_PRINT_BLANKS
00B2 2102  0042'             134                      LD       R2, #FM_MSG_4
00B6 5F00  015E'             135                      CALL     FM_PRINT_MSG
00BA 2101  000A              136                      LD       R1,#10    !MENTOR SEG #!
00BE 2102  0001              137                      LD       R2,#1     !ENTRY #!
00C2 5F00  0000*             138                      CALL     DELETE_SEG
00C6 9E08                    139                      RET
00C8                         140                  END DELETE_CALL
                             141
                             142 !PAGE
```

```
!
00C8                          MK_CALL              PROCEDURE

                              ENTRY
00C8 2103  0019                   LD     R3,#25
00CC 5F00  01C6'                  CALL   FM_PRINT_BLANKS
00D0 2102  00A8'                  LD     R2,#FM_MSG_8
00D4 5F00  015E'                  CALL   FM_PRINT_MSG
00D8 2101  000A                   LD     R1,#10   !MENTOR_SEG_NO!
00DC 2102  0001                   LD     R2,#1   !ENTRY_NO!
00E0 2103  0002                   LD     R3,#0   !WRITE ACCESS DESIRED!
00E4 5F00  0000*                  CALL   MAKE_KNOWN
00E8 9E08                         RET
00EA                          END MK_CALL



00EA                          TERMINATE_CALL              PPOCEDURE

                              ENTRY
00EA 2103  0019                   LD     R3,#25
00EE 5F00  01C6'                  CALL   FM_PRINT_BLANKS
00F2 2102  008D'                  LD     R2,#FM_MSG_7
00F6 5F00  015E'                  CALL   FM_PRINT_MSG
00FA 2101  000B                   LD     R1,#11   !SEG #!
00FE 5F00  0000*                  CALL   TERMINATE
0102 9E08                         RET
0104                          END TERMINATE_CALL
          !PAGE
```

```
!
0104                    SWAP_IN_CALL                    PROCEDURE

                        ENTRY
0104 2103  0019             LD       R3,#25
0108 5F00  01C6'            CALL     FM_PRINT_BLANKS
010C 2102  005A'            LD       R2, #FM_MSG_5
0110 5F00  015E'            CALL     FM_PRINT_MSG
0114 2101  000B             LD       R1,#11    ! SEG #!
0118 5F00  0000*            CALL     SM_SWAP_IN
011C 9E08                   RET
011E                    END SWAP_IN_CALL



011E                    SWAP_OUT_CALL                   PROCEDURE

                        ENTRY
011E 2103  0019             LD       R3,#25
0122 5F00  01C6'            CALL     FM_PRINT_BLANKS
0126 2102  0073'            LD       R2, #FM_MSG_6
012A 5F00  015E'            CALL     FM_PRINT_MSG
012E 2101  000B             LD       R1,#11    ! SEG #!
0132 5F00  0000*            CALL     SM_SWAP_OUT
0136 9E08                   RET
0138                    END SWAP_OUT_CALL
         !PAGE
```

```
0138                  FM_PRINT_RET_FROM_KER       PROCEDURE

                      ENTRY
0138 5F00  0192'          CALL    FM_DELAY
013C 2103  0019           LD      R3,#25
0140 5F00  01C6'          CALL    FM_PRINT_BLANKS
0144 2102  002B'          LD      R2,#FM_MSG_3
0148 5F00  0FC0           CALL    WRITELN
014C 5F00  0FD4           CALL    CRLF
0150 2103  004B           LD      R3,#75
0154 5F00  01AE'          CALL    FM_PRINT_LINE
0158 5F00  0FD4           CALL    CRLF
015C 9E08                 RET
015E                  END FM_PRINT_RET_FROM_KER



015F                  FM_PRINT_MSG                PROCEDURE

                      ENTRY
015F 5F00  0FC0           CALL    WRITELN
0162 5F02  0192'          CALL    FM_DELAY
0166 5F00  0FD4           CALL    CRLF
016A 2103  004B           LD      R3, #75
016E 5F00  01AE'          CALL    FM_PRINT_LINE
0172 5F00  0FD4           CALL    CRLF
0176 9E08                 RET
0178                  END FM_PRINT_MSG


       !PAGE
```

```
!
0178                          PRINT_IO_IS_SIGNALLER                      PROCEDURE

                              ENTRY
0178 2103   0019                  LD      R3,#25
017C 5F00   01C6'                 CALL    FM_PRINT_BLANKS
0180 2102   0000'                 LD      R2, #FM_MSG_1
0184 5F00   0FC0                  CALL WRITELN
0188 5F00   0FD4                  CALL CRLF
018C 5F00   0192'                 CALL FM_DELAY
0190 9E08                         RET
0192                          END PRINT_IO_IS_SIGNALLER



0192                FM_DELAY      PROCEDURE
                                  !*********************!
                                  ! PRODUCES 2 SEC DELAY !
                                  !*********************!
                              ENTRY
0192 2102   000A                  LD      R2, #COUNT
0196 2101   01F4                  LD      R1, #TIME
                                  DO
019A 0B02   0000                   CP     R2, #0
019E 5E0E   01A6'                  IF EQ THEN EXIT FI
01A2 5E08   01AC'
01A6 AB20                          DEC    R2
01A8 7B1D                          MREQ   R1
01AA E8F7                         OD
01AC 9E08                         RET
01AE                          END FM_DELAY


                !PAGF
```

```
                    !
01AE                263     FM_PRINT_LINE         PROCEDURE
                    264                           ! ******************** !
                    265                           ! PRINTS LINE LENGTH  !
                    266                           ! SPEC IN R3.         !
                    267                           ! ******************** !
                    268             ENTRY
01AE C82D           269                 LDB       RL0, #DASH
                    270                 DO
01B0 0B03  0000     271                  CP       R3, #0
01B4 5E0E  01BC'    272                  IF EQ THEN EXIT FI
01B8 5F0E  01C4'
01BC 5F00  0FC8     273                  CALL WRITE
01C0 AB30           274                  DEC      R3
01C2 E8F6           275                 OD
01C4 9E08           276                 RET
01C6                277             END FM_PRINT_LINE
                    278
                    279
01C6                280     FM_PRINT_BLANKS       PROCEDURE
                    281                           ! ******************** !
                    282                           ! PRINTS NUMBER OF    !
                    283                           ! BLANKS SPEC IN R3.  !
                    284                           ! ******************** !
                    285             ENTRY
01C6 C820           286                 LDB       RL0, #SPACE
                    287                 DO
01C8 0B03  0000     288                  CP       R3, #0
01CC 5E0E  01D4'    289                  IF EQ THEN EXIT FI
01D0 5F0E  01DC'
01D4 5F20  0FC8     290                  CALL WRITE
01D8 AB30           291                  DEC      R3
01DA E8F6           292                  OD
01DC 9E08           293                 RET
01DE                294             END FM_PRINT_BLANKS
                    295
                    296         END FM_PROCESS
                    297 !PAGE
```

```
!
 2 IO_PROCESS       MODULE
 3
 4 ! VERS 1.8       !
 5
 6  CONSTANT
 7   WRITE          := %0FC8          ! TYWR MON CALL !
 8   WRITELN        := %0FC0          ! PUTMSG MON CALL !
 9   CRLF           := %0FD4          ! MON CALL        !
10   RETURN_TO_MONITOR  := %A902      ! HBUG REENTRY     !
11
12   COUNT := 10
13   TIME  := 500
14
15   SPACE := %20
16   DASH  := %2D
17
18   IO_MGR         := %20
19   FILE_MGR       := %40
20   MEM_MGR        := %00
21
22 EXTERNAL
23   MAKE_KNOWN              PROCEDURE
24   TERMINATE               PROCEDURE
25   SM_SWAP_IN              PROCEDURE
26   SM_SWAP_OUT             PROCEDURE
27   SIGNAL                  PROCEDURE
28   WAIT                    PROCEDURE
29 !PAGE
```

```
!
                                30 $SECTION IO_DATA
                                31  INTERNAL
                                32   ! * * * * MESSAGES * * * * !
0000 10  49  4F                 33   IO_MSG_1 ARRAY [* BYTE]:='%10IO: READ COMMAND'
0003 3A  20  52
0006 45  41  44
0009 20  43  4F
000C 4D  4D  41
000F 4E  44
0011 0F  49  4F                 34   IO_SEND  ARRAY [* BYTE]:='%0FIO: SIGNAL FM  '
0014 3A  20  53
0017 49  47  4E
001A 41  4C  20
001D 46  4D  20
0020 20
0021 1B  49  4F                 35   IO_MSG_2 ARRAY [* BYTE]:='%1BIO: CALL KERNEL(MAKE_KNOWN)'
0024 3A  20  43
0027 41  4C  4C
002A 20  4B  45
002D 52  4E  45
0030 4C  28  4D
0033 41  4B  45
0036 5F  4B  4E
0039 4F  57  4E
003C 29
003D 18  49  4F                 36   IO_MSG_3 ARRAY [* BYTE]:='%18IO: CALL KERNEL(SWAP_IN)'
0040 3A  20  43
0043 41  4C  4C
0046 20  4B  45
0049 52  4E  45
004C 4C  28  53
004F 57  41  50
0052 5F  49  4E
0055 29
                                37 !PAGE
```

```
!
0056 19  49  4F        38   IO_MSG_4 ARRAY [* BYTE]:='%19IO: CALL KERNEL(SWAP_OUT)'
0059 3A  20  43
005C 41  4C  4C
005F 20  4F  45
0062 52  4E  45
0065 4C  28  53
0068 57  41  50
006B 5F  4F  55
006E 54  29
0070 1A  49  4F        39   IO_MSG_5 ARRAY [* BYTE]:='%1AIO: CALL KERNEL(TERMINATE)'
0073 3A  20  43
0076 41  4C  4C
0079 20  4F  45
007C 52  4E  45
007F 4C  28  54
0082 45  52  4D
0085 49  4E  41
0088 54  45  29
008F 16  49  4F        40   IO_MSG_6 ARRAY [* BYTE]:='%16IO: RETURN FROM KERNEL'
008E 3A  20  52
0091 45  54  55
0094 52  4E  20
0097 46  52  4F
009A 4D  20  4B
009D 45  52  4E
00A0 45  4C
00A2                   41  IO_MSG_ARRAY  ARRAY [16  BYTE]
                       42 !PAGE
```

```
!
                                43 INTERNAL
                                44
                                45 $SECTION IO_PROC
                                46
                                47
0000                            48   IO_MAIN PROCEDURE
                                49              ENTRY
                                50              DO !** DO FOREVER **!
                                51              ! ** PRINT: "READ COMAND#" ** !
0000 2102  0000'                52                  LD      R2, #IO_MSG_1
0004 5F00  0082'                53                  CALL    IO_PRINT_MSG
                                54              ! ** SIGNAL FM TO CREATE ** !
                                55              ! **   AND WAIT              ** !
0008 5F00  0074'                56                  CALL    IO_SIGNAL_CALL
000C 760E  00A2'                57                  LDA     R8,IO_MSG_ARRAY[0]
0010 5F00  0000*                58                  CALL    WAIT
0014 2102  0000'                59                  LD      R2, #IO_MSG_1
0018 5F00  0082'                60                  CALL    IO_PRINT_MSG
                                61              ! ** SIGNAL FM TO MAKE_KNOWN & SWAP_IN ** !
                                62              ! **    AND WAIT         ** !
001C 5F00  0074'                63                  CALL    IO_SIGNAL_CALL
0020 7608  00A2'                64                  LDA    R8,IO_MSG_ARRAY[0]
                                65
0024 5F00  0000*                66                  CALL WAIT
0028 2102  0000'                67                  LD      R2,#IO_MSG_1
002C 5F00  0082'                68                  CALL    IO_PRINT_MSG
                                69                  ! IO "READ" -- MAKE_KNOWN AND SWAP_IN !
0030 5F00  00AA'                70                  CALL    IO_MK_CALL
0034 5F00  00C4'                71                  CALL    IO_SWAP_IN_CALL
0038 2102  0000'                72                  LD      R2,#IO_MSG_1
003C 5F00  0082'                73                  CALL    IO_PRINT_MSG
                                74                  ! SIGNAL FM TO SWAP OUT AND TERMINATE !
0040 5F00  0074'                75                  CALL    IO_SIGNAL_CALL
0044 7608  00A2'                76                  LDA     R8,IO_MSG_ARRAY[0]
                                77 !PAGE
```

```
!
0048 5F00  0000*                    CALL    WAIT
004C 2102  0000'                    LD      R2,#IO_MSG_1
0050 5F02  0082'                    CALL    IO_PRINT_MSG
                                    ! IO SWAP OUT AND TERMINATE !
0054 5F00  00D6'                    CALL    IO_SWAP_OUT_CALL
0058 5F20  00E8'                    CALL    IO_TERMINATE_CALL
005C 2102  0000'                    LD      R2,#IO_MSG_1
0060 5F00  0082'                    CALL    IO_PRINT_MSG
                                    ! SIGNAL FM TO DELETE !
0064 5F00  0074'                    CALL    IO_SIGNAL_CALL
0068 7608  00A2'                    LDA     R8,IO_MSG_ARRAY[0]
006C 5F00  0000*                    CALL    WAIT
0070 E8C7                       OD !**REPEAT FOREVER**!
0072 9E08                       RET
0074                            END IO_MAIN


0074                   IO_SIGNAL_CALL             PROCEDURE

                                ENTRY
0074 2101  0040                     LD      R1, #FILE_MGR !LD SIGNALED PROC #!
0078 7608  0011'                    LDA     R8,IO_SEND[0]
007C 5F00  0000*                    CALL SIGNAL
0080 9E08                           RET
0082                            END IO_SIGNAL_CALL
          !PAGE
```

```
!
0082                       IO_PRINT_MSG          PROCEDURE

                                   ENTRY
0082 5F00  0FC0                        CALL WRITELN
0086 5F00  0FD4                        CALL CRLF
008A 5F00  00FA'                       CALL IO_DELAY
008E 2103  004B                        LD       R3, #75
0092 5F00  0116'                       CALL IO_PRINT_LINE
0096 5F00  0FD4                        CALL CRLF
009A 9E08                              RET
009C                               END IO_PRINT_MSG

009C                       IO_PRINT_RET_FROM_KER         PROCEDURE

                                   ENTRY
009C 5F00  00FA'                       CALL     IO_DELAY
00A0 2102  008B'                       LD       R2,#IO_MSG_6
00A4 5F00  0082'                       CALL     IO_PRINT_MSG
00A8 9E08                              RET
00AA                               END IO_PRINT_RET_FROM_KER



00AA                       IO_MK_CALL   PROCEDURE

                                   ENTRY
00AA 2102  0021'                       LD       R2,#IO_MSG_2
00AE 5F00  0082'                       CALL     IO_PRINT_MSG
00B2 2101  000A                        LD       R1,#10  !MENTOR_SEG_NO!
00B6 2102  0001                        LD       R2,#1  !ENTRY_NO!
00BA 2103  0001                        LD       R3,#1  !READ ACCESS DESIRED!
00BE 5F00  0000*                       CALL     MAKE_KNOWN
00C2 9E08                              RET
00C4                               END IO_MK_CALL
                       !PAGE
```

```
!
00C4                    139     IO_SWAP_IN_CALL       PROCEDURE
                        140
                        141             ENTRY
00C4 2102  003D'        142                 LD        R2,#IO_MSG_3
00C8 5F00  0082'        143                 CALL      IO_PRINT_MSG
00CC 2101  000B         144                 LD        R1,#11   !SEG #!
00D0 5F00  0000*        145                 CALL      SM_SWAP_IN
00D4 9E08               146                 RET
00D6                    147             END IO_SWAP_IN_CALL
                        148
                        149
00D6                    150     IO_SWAP_OUT_CALL      PROCEDURE
                        151
                        152             ENTRY
00D6 2102  0056'        153                 LD        R2,#IO_MSG_4
00DA 5F00  0082'        154                 CALL      IO_PRINT_MSG
00DF 2101  000B         155                 LD        R1,#11   !SEG #!
00E2 5F00  0000*        156                 CALL      SM_SWAP_OUT
00E6 9E08               157                 RET
00E8                    158             END IO_SWAP_OUT_CALL
                        159
                        160
00E8                    161     IO_TERMINATE_CALL     PROCEDURE
                        162
                        163             ENTRY
00E8 2102  0070'        164                 LD        R2,#IO_MSG_5
00EC 5F00  0082'        165                 CALL      IO_PRINT_MSG
00F0 2101  000B         166                 LD        R1,#11   !SEG #!
00F4 5F00  0000*        167                 CALL      TERMINATE
00F8 9E08               168                 RET
00FA                    169             END IO_TERMINATE_CALL
                        170 !PAGE
```

```
!
00FA                     171    IO_DELAY      PROCEDURE
                         172                  !*********************!
                         173                  ! PRODUCES 2 SEC DELAY !
                         174                  !*********************!
                         175               ENTRY
00FA 2102  000A          176                  LD      R2, #COUNT
00FE 2101  01F4          177                  LD      R1, #TIME
                         178                  DO
0102 0B02  0000          179                   CP     R2, #0
0106 5E0E  010E'         180                   IF EQ THEN EXIT FI
010A 5E08  0114'
010E AB20                181                   DEC    R2
0110 7B1D                182                   MREQ   R1
0112 E8F7                183                  OD
0114 9E08                184                  RET
0116                     185               END IO_DELAY
                         186
0116                     187    IO_PRINT_LINE         PROCEDURE
                         188                          ! ******************* !
                         189                          ! PRINTS LINE LENGTH  !
                         190                          ! SPEC IN R3.         !
                         191                          ! ******************* !
                         192               ENTRY
0116 C82D                193                  LDB     RL0, #DASH
                         194                  DO
0118 0B03  0000          195                   CP     R3, #0
011C 5E0F  0124'         196                   IF EQ THEN EXIT FI
0120 5E08  012C'
0124 5F00  0FC8          197                   CALL WRITE
0128 AB30                198                   DEC    R3
012A E8F6                199                  OD
012C 9E08                200                  RET
012E                     201               END IO_PRINT_LINE
                         202 END IO PROCESS
                         203 !PAGE
```

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